HYDROLOGIC RESTORATION OF SOUTHERN GOLDEN GATE ESTATES

FINAL SUBGRANT PERFORMANCE REPORT

Prepared for
Florida Coastal Management Program

by

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TASK 3.5.02

CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

The planning process for formulation of a set of economically and environmentally feasible measures for restoration of Southern Golden Gate Estates (SGGE) involved development of a continuous process hydrologic-hydraulic simulation model of the watershed by the U.S. Environmental Agency's watershed modeling program package Hydrologic Simulation Program - Fortran (HSPF). A quantitative evaluation of the impacts of large scale land development in the Golden Gate Estates on the overall hydrology of the area was performed by continuously simulating the hydrologic-hydraulic characteristics of the watershed for a 23-year period. Detailed descriptions of model development, earlier phases of the calibration and verification of various model segments and assessment of the human induced impacts on the overall hydrology of the region was provided in the first three quarterly reports. The first report reviewed the project background and the historical development of Golden Gate Estates. A description of the existing hydrology was included, as well as a detailed summary of the study design and the formulation of the required data base. The second report describes the development of the model and of the phase I calibration results for the northern Faka Union Canal subbasin. Report three recounts the second phase of calibration, presents some preliminary observations of the model performance and existing conditions in the SGGE basin and proposes three preliminary alternative scenarios. This report provides a summary of the last phase of model calibration and the verification process, identification of alternative hydrologic restoration measures, evaluation of the performance of those alternative measures, and presents a recommended restoration plan.

II. CALIBRATION ANALYSIS-PHASE THREE

A. METHOD OF CALIBRATION

The process calibrating the hydrologic-hydraulic model for the Southern Golden Gate Estates (SGGE) watershed was extended to cover each of the subbasins where recorded data on canal stages and flows were available. The iterative process of comparing the simulation results with observed historic data for the Faka Union Canal at its outlet was also continued in this phase to refine the model.

In general, the following four-step method for calibration was performed.

1) Water Balance Equation:

The basic water balance equation for the hydrologic processes simulated in HSPF is:

Precipitation - Actual ET $\pm$ Storage $\pm$ Basin Transfers = Runoff

where

Storage = total moisture stored in the six simulated surface and subsurface storage zones, namely the interception, surface, interflow, upper zone, lower zone, and active groundwater storages

Basin Transfers = flows across the watershed boundaries (i.e. underflow at gage locations)

Runoff = observed runoff at a gage

ET = Evapotranspiration

The purpose of looking at this equation first is twofold. First, it allows the modeler to make sure that all of the incoming precipitation is accounted for and that the amounts are reasonable. Secondly, it allows for an initial overall estimate of runoff and evaporation volumes of the overall hydrologic budget.

2) Seasonal or low flows

The second step involves adjusting those parameters that affect low flows or groundwater flows in the surficial aquifer.

3) Hydrograph shape and peak streamflows

It is assumed through steps one and two that volumes and low flows are calibrated. This step involves trading surface flow for interflow and vice versa to better match peak flows, time to peak, and the rising and the recession limbs of the hydrographs.

4) Refinement

This step involves looking at specific events and trying to improve simulation without undoing anything done in steps one to three. One example of "fine tuning" refinement is trying to better simulated storms that break dry periods.

Each of these steps were followed in the three calibration phases for the SGGE area.

B. LOCATION OF CALIBRATION STATIONS

During phase two calibration, the approach was to find an overall calibration of the whole basin using the streamflow and stage data near the outlet of the Faka Union Canal and then narrow it down to improve individual subbasin calibration. The remaining subbasins that were looked at during the phase three calibration were (Figure 1):

1) Stumpy Strand - Lucky Lake Strand Area using 12 months of stage data at north Merritt canal (55th Avenue SE);

2) the subbasin contributing to north Miller canal using nine years of stage data recorded at north Miller canal (26th Avenue SE);

3) the southwestern subbasin using seven years of randomly collected stage data at Miller Canal Weir No. 1.

C. PERVIOUS LAND SEGMENTS AND REACH-RESERVOIR NETWORK FOR PHASE THREE SIMULATION

The SGGE study area and canal system were divided into 35 pervious land segments (PLS) and 34 reach-reservoir (RCHRES) segments during phase two calibration. The PLS divisions were based on homogeneity of land use, topography, soils data and similar meteorologic influence as discussed in previous reports. Each RCHRES possessed

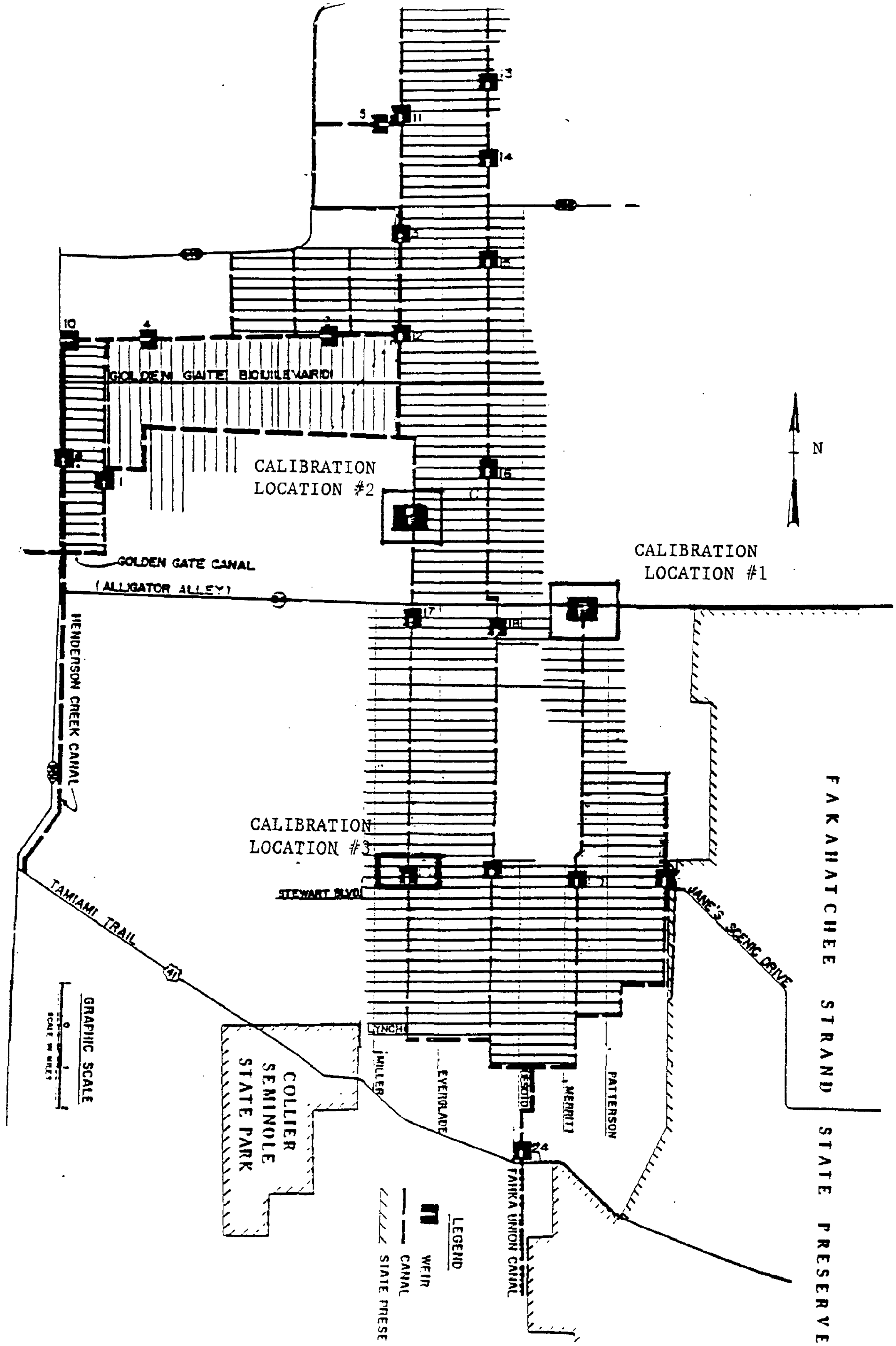


FIGURE 1. Calibration Locations for Phase Three

similar hydraulic characteristics and terminated at critical points in the canal system. This same model configuration for the SGGE watershed and canal system was maintained during phase three calibration.

D. PERIOD OF CALIBRATION

The time periods used for calibration in phase three were based solely on the availability of data. The periods of calibration were:

1)	Merritt Canal at 55th Avenue SE	1992
2)	Miller Canal at 26th Avenue SE	1983-1992
3)	Miller Canal at Weir No. 1	1986-1992

One drawback of the longer simulation period (i.e. greater than 3-5 years) is that it is difficult to find a longer time period where residential and agricultural developments have not influenced the runoff characteristics of the basin. This is the case for calibration locations two and three. However, it was decided to use all available data to provide a great variety of meteorological conditions and use as many data points as possible. Stage data at Miller Canal Weir No. 1 was collected randomly at approximately seven to ten day intervals. Therefore, using all seven years of observed data allowed more data points to be compared.

E. INITIAL CONDITIONS

The initial estimates of the input parameters for the hydrologic simulation were those parameters that were calibrated during the first two phases. The ranges of the typical values of the Pervious Land Module (PERLND) parameters were adapted for south Florida hydrologic conditions from such sources as the HSPF Application Guide, several earlier HSPF application project reports, and consultation with Dr. Norm Crawford, the principal author of the program. Some of the parameters were further adjusted so as to better simulate the individual subbasins yet maintaining the overall balance obtained for the entire basin.

F. SENSITIVITY ANALYSIS OF CALIBRATION PARAMETERS

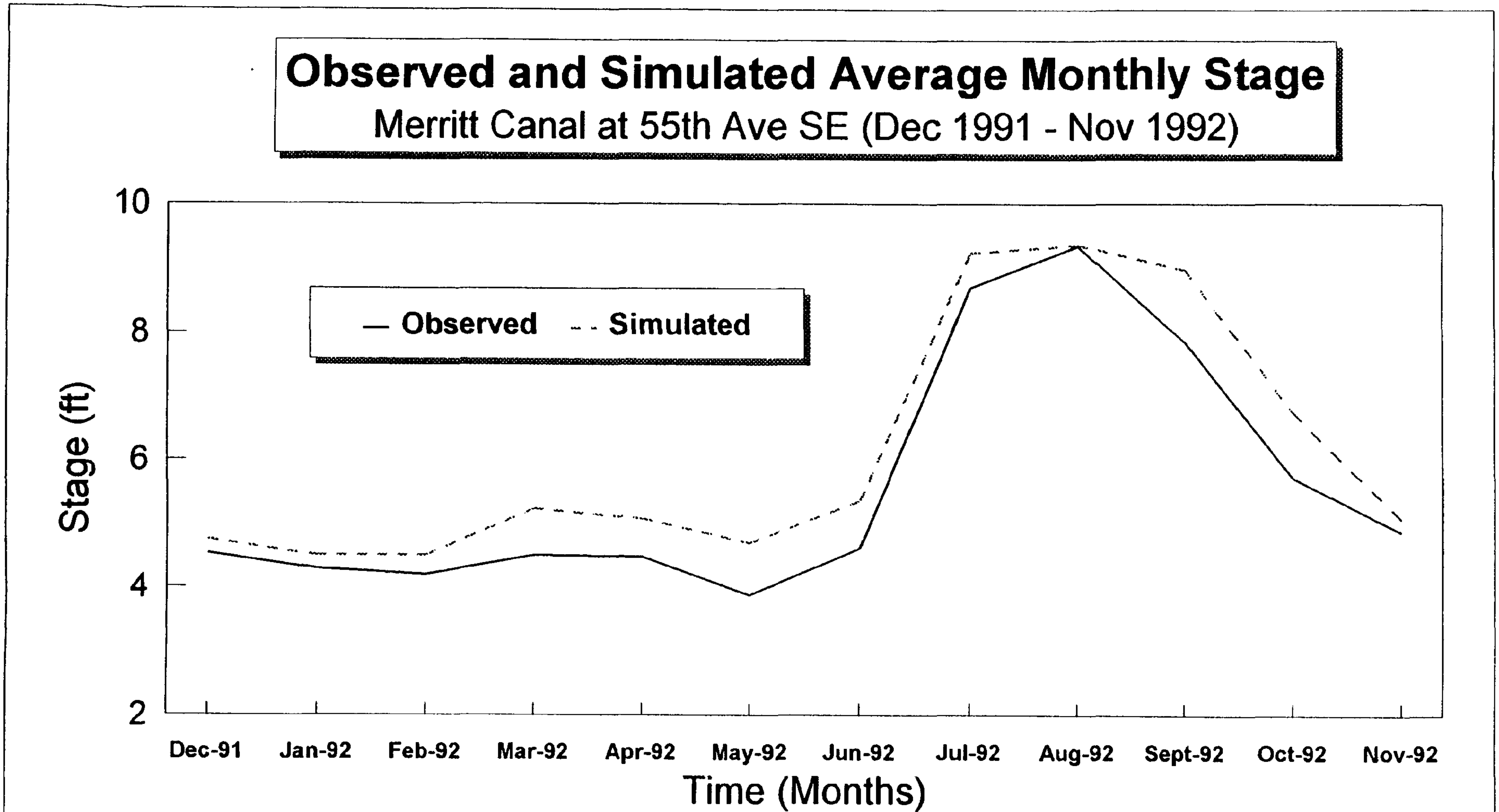
The sensitivity of the selected calibration parameters on the overall simulation of the hydrologic processes of the SGGE was discussed in the last two quarterly reports and showed similar characteristics in phase three calibration.

In addition to adjusting the prominent parameters on soil storages, sources and sinks and various coefficients as described in the last report, the function tables (FTABLES) or "function tables" which describe the stage-volume-discharge relationship for the canals were modified for additional hydraulic calibration. Additional columns were added to the Faka Union Canal FTABLES to represent blockages to flow (both aquatic weeds and flashboards) and groundwater seepage from the canal near the Naples wellfield. The use of multiple columns did improve the results of simulation.

G. SUMMARY OF CALIBRATION FOR PHASE THREE

The model simulation results that compare observed and simulated canal stages at the calibration points on the Miller and Merritt canals are shown in Figures 2 through 4.

The results from the phase three calibration for the three subbasins were a significant improvement over the first two phases of calibration. The factors that influenced the observed runoff, such as time variant changes in the canals and to the weirs as discussed in the last quarterly report, still complicate the modeling. However, better calibration results were observed. One reason could be that the observed data is of more reliable quality. Another reason is the use of stage values rather than discharge measurements. The discharge measurements used for calibration in phase two were extrapolated from rating curves that related to the observed stage values with discharge. The frequency of some discharge measurements were very widely distributed and did not adequately reflect the operation of stop logs at the water control structures. The use of weekly measured stage records to calibrate



Observed and Simulated Average Monthly Stage
Merritt Canal at 55th Ave SE (Dec 1991 - Nov 1992)
— Observed
- - Simulated
Stage (ft)
10
8
6
4
2
Dec-91
Jan-92
Feb-92
Mar-92
Apr-92
May-92
Jun-92
Jul-92
Aug-92
Sept-92
Oct-92
Nov-92
Time (Months)

FIGURE 2

Observed and Simulated Average Monthly Stage
Miller Canal at 26th St. SE (May 1983 - Nov 1992)

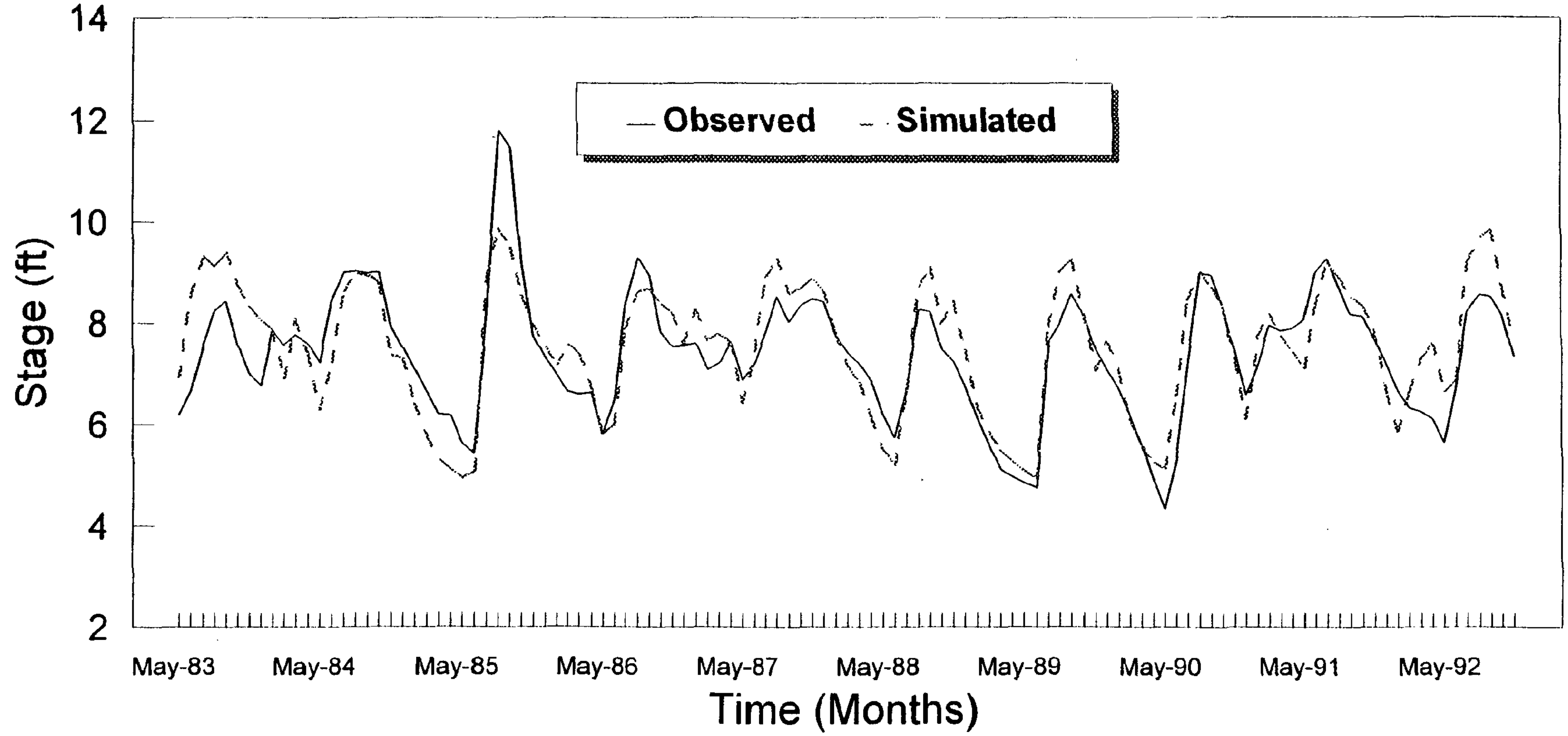
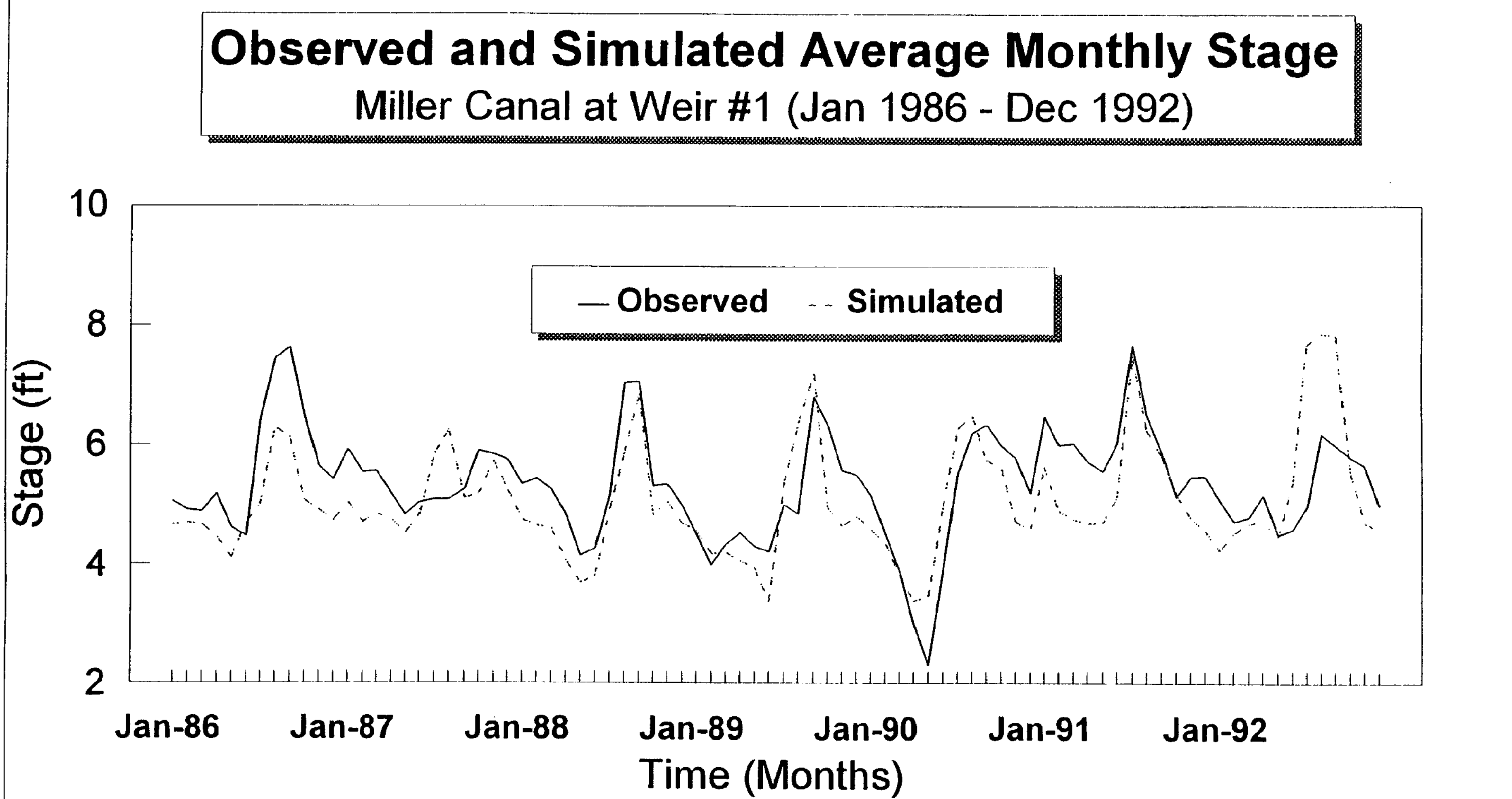


FIGURE 3



Observed and Simulated Average Monthly Stage
Miller Canal at Weir #1 (Jan 1986 - Dec 1992)
— Observed
- - Simulated
Stage (ft)
10
8
6
4
2
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)

FIGURE 4

the model at Miller Canal Weir No. 1, Faka Union Canal Weirs No. 2 and 4, and continuous records on Miller Canal at 26th Avenue SE and Merritt Canal at 55th Avenue SE provided a better database for calibration. Another factor is the shorter simulated period used for the Stumpy Strand-Lucky Lake Strand subbasin for the Merritt Canal. The use of only one year of data for calibration is easier to perform than calibrating for several years. With the exception of Faka Union Weir No. 5 location, the calibration locations near the headwaters of the canals showed better results than those further downstream. Some accuracy was lost in hydraulic routing by use of the equation of continuity in the hydraulic section (HYDR) of the Reach-Reservoir (RCHRES) module as the runoff is conveyed through the canals. The Faka Union Canal flow characteristics have varied more over the years than those of the Miller and Merritt canals due to operation with more water control structures.

H. FINAL CALIBRATION PARAMETERS

The final set of calibration parameters used for the simulation of SGGE are shown in Table 1. A list of parameter abbreviations from the HSPF program is shown in Appendix A.

TABLE 1

FINAL PARAMETERS FOR HSPF SIMULATION OF SGGE

Parameter Set 1

PLS	FOREST	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
1	0	8	0.09	1660	0.00061	1.0	0.980
2	0	8	0.04	1660	0.00032	0.0	0.940
3	0	4	0.04	1660	0.00019	0.0	0.940
4	0	4	0.04	1660	0.00016	0.0	0.940
5	0	8	0.09	1660	0.00014	0.0	0.960
7	0	6	0.09	1660	0.00033	0.0	0.960
8	0	4	0.09	1660	0.00035	0.0	0.940
9	0	4	0.04	1660	0.00014	0.0	0.940
10	0	2	0.04	1660	0.00008	0.0	0.940
11	0	4	0.04	1660	0.00032	0.0	0.940
12	0	4	0.10	1660	0.00013	0.0	0.940
13	0	4	0.09	1660	0.00013	0.0	0.940
14	0	4	0.04	1660	0.00002	0.0	0.940
15	0	4	0.10	1660	0.00019	0.0	0.940
16	0	4	0.04	1660	0.00002	0.0	0.940
17	0	4	0.04	1660	0.00038	0.0	0.940
18	0	6	0.09	1660	0.00021	0.0	0.940
19	0	2	0.04	1660	0.00021	0.0	0.940
20	0	2	0.04	1660	0.00030	0.0	0.940
21	0	8	0.09	1660	0.00013	0.0	0.940
22	0	4	0.04	1660	0.00012	0.0	0.940
23	0	4	0.04	1660	0.00032	0.0	0.940
24	0	4	0.04	1660	0.00018	0.0	0.940
25	0	4	0.04	1660	0.00025	0.0	0.940
26	0	4	0.04	1660	0.00013	0.0	0.940
27	0	2	0.04	1660	0.00008	0.0	0.940
28	0	2	0.04	1660	0.00008	0.0	0.940
29	0	2	0.04	1660	0.00008	0.0	0.940
30	0	4	0.04	1660	0.00042	0.0	0.920
31	0	4	0.06	1660	0.00032	0.0	0.940
32	0	4	0.04	1660	0.00018	0.0	0.940
33	0	4	0.04	1660	0.00008	0.0	0.920
34	0	4	0.04	1660	0.00032	0.0	0.940
35	0	6	0.06	1660	0.00032	0.0	0.940
36	0	4	0.04	1660	0.00020	0.0	0.920
37	0	4	0.04	1660	0.00020	0.0	0.920

PLS = Pervious Land Segment
FOREST = fraction of winter forest transpiration
LZSN = lower zone nominal soil storage (in)
INFILT = index to mean infiltration rate (in/hr)
LSUR = length of overland flow plane (ft)

TABLE 1 (Continued)

SLSUR = slope of overland flow plane
KVARY = groundwater recession behavior parameter (1/in)
AGWRC = active groundwater recession coefficient (1/day)

Parameter Set 2

PLS	PETMAX	PETMIN	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
1-4	40	35	2.0	2.0	0.5	0.0	0.40
5-6	40	35	1.0	2.0	0.1	0.0	0.40
7	40	35	1.0	2.0	0.3	0.0	0.40
8-9	40	35	2.0	2.0	0.3	0.0	0.40
10	40	35	2.0	2.0	0.3	0.0	0.60
11	40	35	2.0	2.0	0.3	0.0	0.70
12	40	35	2.0	2.0	0.3	0.0	0.40
13	40	35	2.0	2.0	0.3	0.0	0.40
14	40	35	2.0	2.0	0.3	0.0	0.60
15	40	35	2.0	2.0	0.3	0.0	0.40
16	40	35	2.0	2.0	0.3	0.0	0.60
17	40	35	2.0	2.0	0.3	0.0	0.70
18	40	35	2.0	2.0	0.3	0.0	0.70
19	40	35	2.0	2.0	0.3	0.0	0.40
20	40	35	2.0	2.0	0.3	0.0	0.70
21-26	40	35	2.0	2.0	0.3	0.0	0.40
27	40	35	2.0	2.0	0.3	0.0	0.60
28	40	35	2.0	2.0	0.3	0.0	0.60
29	40	35	2.0	2.0	0.3	0.0	0.60
30	40	35	2.0	2.0	0.3	0.0	0.70
31	40	35	2.0	2.0	0.3	0.0	0.40
32	40	35	2.0	2.0	0.3	0.0	0.40
32	40	35	2.0	2.0	0.3	0.0	0.40
33	40	35	2.0	2.0	0.3	0.0	0.70
34	40	35	2.0	2.0	0.3	0.0	0.40
35	40	35	2.0	2.0	0.3	0.0	0.60
36-37	40	35	2.0	2.0	0.3	0.0	0.70

PETMAX = air temperature which signals a change in ET calculation (F), only used if snow is considered
PETMIN = air temperature which signals a change in ET calculation (F), only used if snow is considered
INFEXP = exponent in infiltration equation
INFILD = ratio of max/min infiltration rate
DEEPFR = fraction of groundwater lost to deep aquifer
BASETP = fraction of ET from active groundwater outflow
AGWETP = fraction of ET from active groundwater storage

TABLE 1 (Continued)

Parameter Set 3

PLS	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
1	0.100	1.80	0.70	5.00	0.90	0.50
2	0.100	0.50	0.70	5.00	0.95	0.30
3	0.150	0.50	0.70	5.00	0.95	0.70
4	0.150	0.50	0.70	5.00	0.95	0.80
5	0.150	0.50	0.70	5.00	0.90	0.80
6	0.150	0.50	0.70	5.00	0.90	0.80
7	0.100	0.50	0.70	5.00	0.90	0.60
8	0.150	0.50	0.70	5.00	0.95	0.80
9	0.150	0.50	0.70	5.00	0.90	0.80
10	0.150	0.50	0.70	5.00	0.95	0.70
11	0.150	0.50	0.70	5.00	0.90	0.70
12	0.150	0.50	0.70	5.00	0.95	0.70
13	0.150	0.50	0.70	5.00	0.95	0.70
14	0.100	0.50	0.70	5.00	0.95	0.40
15	0.150	0.50	0.70	5.00	0.95	0.70
16	0.150	0.50	0.70	5.00	0.95	0.70
17	0.150	0.50	0.70	5.00	0.95	0.70
18	0.150	0.50	0.70	5.00	0.95	0.70
19	0.100	0.50	0.70	5.00	0.95	0.40
20	0.150	0.50	0.70	5.00	0.95	0.70
21	0.100	0.50	0.70	5.00	0.95	0.30
22	0.150	0.50	0.70	5.00	0.95	0.70
23	0.150	0.50	0.70	5.00	0.90	0.70
24	0.100	0.50	0.70	5.00	0.95	0.40
25	0.150	0.50	0.70	5.00	0.90	0.80
26	0.150	0.50	0.70	5.00	0.95	0.70
27	0.150	0.50	0.70	5.00	0.95	0.70
28	0.100	0.50	0.70	5.00	0.95	0.40
29	0.150	0.50	0.70	5.00	0.95	0.70
30	0.200	0.50	0.70	5.00	0.95	0.90
31	0.150	0.50	0.70	5.00	0.95	0.80
32	0.150	0.50	0.70	5.00	0.95	0.40
33	0.150	0.50	0.70	5.00	0.95	0.90
34	0.150	0.50	0.70	5.00	0.95	0.70
35	0.150	0.50	0.70	5.00	0.95	0.40
36	0.200	0.50	0.70	5.00	0.95	0.90
37	0.100	0.50	0.70	5.00	0.95	0.40

CEPSC = interception storage capacity (in)
NSUR = Manning's n for overland flow
UZSN = upper zone nominal soil storage (in)
INTFW = interflow inflow parameter
IRC = interflow recession rate (1/day)
LZETP = lower zone evapotranspiration parameter

TABLE 1 (Continued)

Monthly Variable Parameters

LZETP

PLS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
2	0.2	0.2	0.2	0.2	0.2	.05	.05	.05	.05	.05	0.2	0.2
3	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
4-6	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.5	0.4	0.4	0.4	0.4
7	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.3
8-13	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4
14	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
15-17	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.5	0.4	0.4	0.4	0.4
18	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.5	0.4	0.4	0.4	0.4
19	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
20	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
21	0.2	0.2	0.2	0.2	0.2	.05	.05	.05	.05	.05	0.2	0.2
22	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
23	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
24	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
25	0.6	0.7	0.8	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.6
26	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
27	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
28	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
29	0.5	0.6	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
30	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7
31	0.4	0.4	0.5	0.6	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4
32	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
33	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7
34	.25	.25	.25	.25	.40	.40	.40	.40	.25	.25	.25	.25
35	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
36	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7
37	0.3	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3

LZETP = lower zone evapotranspiration parameter

Parameters for Initial Conditions

PLS	CEPS	SURS	UZS	IFWS	LZS	AGWS	GWVS
1	0.00	0.0	0.0	0.0	6.0	1.7	0.00
2	0.00	0.0	0.0	0.0	6.0	1.7	0.00
3	0.00	0.0	0.0	0.0	6.0	3.5	0.00
4	0.00	0.0	0.0	0.0	6.0	2.0	0.00
5	0.00	0.0	0.0	0.0	6.0	1.7	0.00
6	0.00	0.0	0.0	0.0	6.0	2.0	0.00

TABLE 1 (Continued)

PLS	CEPS	SURS	UZS	IFWS	LZS	AGWS	GWVS
7	0.00	0.0	0.0	0.0	6.0	2.0	0.00
8	0.00	0.0	0.0	0.0	5.0	1.7	0.00
9	0.00	0.0	0.0	0.0	5.0	2.0	0.00
10	0.00	0.0	0.0	0.0	4.0	2.0	0.00
11	0.00	0.0	0.0	0.0	4.0	2.0	0.00
12	0.00	0.0	0.0	0.0	4.0	1.7	0.00
13	0.00	0.0	0.0	0.0	4.0	2.0	0.00
14	0.00	0.0	0.0	0.0	4.0	2.0	0.00
15	0.00	0.0	0.0	0.0	4.0	1.7	0.00
16	0.00	0.0	0.0	0.0	4.0	2.0	0.00
17	0.00	0.0	0.0	0.0	3.0	2.0	0.00
18	0.00	0.0	0.0	0.0	4.0	2.0	0.00
19	0.00	0.0	0.0	0.0	3.0	2.0	0.00
20	0.00	0.0	0.0	0.0	3.0	2.0	0.00
21	0.00	0.0	0.0	0.0	6.0	1.7	0.00
22	0.00	0.0	0.0	0.0	6.0	3.0	0.00
23	0.00	0.0	0.0	0.0	4.0	2.0	0.00
24	0.00	0.0	0.0	0.0	4.0	3.0	0.00
25	0.00	0.0	0.0	0.0	4.0	1.7	0.00
26	0.00	0.0	0.0	0.0	4.0	2.0	0.00
27	0.00	0.0	0.0	0.0	4.0	1.7	0.00
28	0.00	0.0	0.0	0.0	4.0	2.0	0.00
29	0.00	0.0	0.0	0.0	3.0	1.7	0.00
30	0.00	0.0	0.0	0.0	4.0	2.0	0.00
31	0.00	0.0	0.0	0.0	4.0	2.0	0.00
32	0.00	0.0	0.0	0.0	4.0	3.0	0.00
33	0.00	0.0	0.0	0.0	3.0	2.0	0.00
34	0.00	0.0	0.0	0.0	4.0	2.0	0.00
35	0.00	0.0	0.0	0.0	3.0	2.0	0.00
36	0.00	0.0	0.0	0.0	4.0	2.0	0.00
37	0.00	0.0	0.0	0.0	3.0	2.0	0.00

CEPS = interception storage at the start of the simulation (in)
SURS = surface storage at the start of the simulation (in)
UZS = upper zone soil storage at the start of the simulation (in)
IFWS = interflow storage at the start of the simulation (in)
LZS = lower zone soil storage at the start of the simulation (in)
AGWS = active groundwater storage at the start of the simulation (in)
GWVS = index to groundwater slope at the start of the simulation (in)

III. VERIFICATION

The model was tested for verification using a seven-year simulation period of 1985 to 1992 and using flow data collected at Faka Union Weir No. 1. This station was used for verification because it records the outflow from the entire watershed and has continuous records of outflow from 1969. The period 1985 to 1992 was chosen because this period covers dry years of 1988-1990, a representative cycle of drought and wet years including the wet years of 1991 and 1992. The results as shown in Figure 5 were similar to the calibration results at weir No. 1 for 1970 to 1984. The overall evaluation of model performance to simulated SGGE is discussed in the next section.

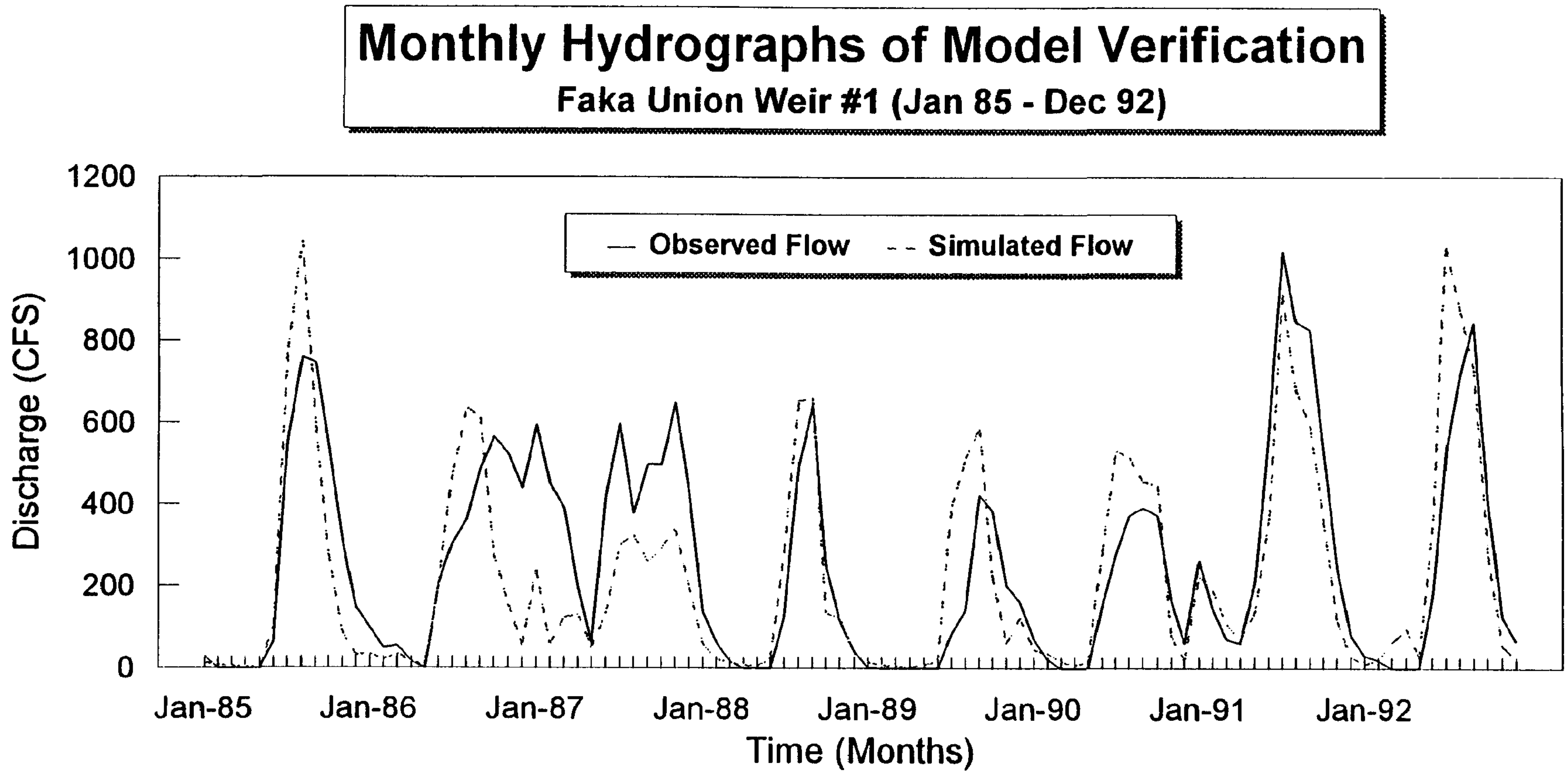

Monthly Hydrographs of Model Verification
Faka Union Weir #1 (Jan 85 - Dec 92)
Discharge (CFS)
1200
1000
800
600
400
200
0
— Observed Flow
- - Simulated Flow
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)

FIGURE 5

IV. EVALUATION OF MODEL PERFORMANCE

A. PRESENCE OF HIGH GROUNDWATER TABLE IN SOUTH FLORIDA HYDROLOGY

One unique element in South Florida hydrology is a seasonally varying water table with a large amplitude. During the wet season it can come up very close to the land surface. The overland flow module of HSPF does not adequately simulate South Florida's sheetflow through wetlands. Throughout a typical year, the water table may vary by several feet, rising above the land surface during the wet season and dropping during the dry season. These cyclic groundwater levels affect such hydrologic processes as soil storages, evapotranspiration from the upper and lower zones of soil horizon, runoff and direction of shallow groundwater flow. Some seasonal variation of parameters is allowed in HSPF (i.e. seasonal canopy changes), but not to the extent that it can model a seasonal high water table.

B. SHEETFLOW HYDRAULICS

When the water table rises above the land surface and large land areas are flooded, the existing Pervious Land (PERLND) module of HSPF does not model the sheetflow characteristics adequately. A typical expanse of natural south Florida wetland has the ability to store an enormous amount of water. The existing overland flow algorithms do not represent the storage effects of these wetlands and thus result overpredicting the runoff peaks. Also evaporation from overland flow is not represented in the model. In wetland areas where overland flow may last weeks, evaporation should be accounted for. Further enhancement to the PERLND module to account for these unique features of south Florida wetlands has been proposed in a recently undertaken study by the District. The enhanced program will be applied later to update the SGGE model.

C. REACH-RESERVOIR (RCHRES) MODULE OF HSPF

The outflow hydrograph is sensitive to the function tables (FTABLES) which represents the stage-storage-outflow characteristics of the canals. In phase three calibration, the runoff hydrographs were better matched at Miller Canal at 26th Avenue SE than at Miller Canal Weir No. 1, a location farther downstream. It is possible that as the runoff is routed through the canals some accuracy is lost. The modification of the RCHRES module to dynamically route flows through canals with flat bed slopes and various control structures should enhance the simulation of flow characteristics in South Florida canals.

D. ASSUMPTIONS IN ALTERNATIVE ANALYSIS

Though the application of the PERLND and RCHRES modules of HSPF may provide a fair representation of the existing SGGE hydrology, the alternatives analysis creates new challenges. Traditional applications of HSPF have included reservoir operations analysis, stormwater management plan development and water quality studies related to waste treatment, urban and/or agricultural management practices. The task of representing alternative measures for restoration of wetland hydrology of SGGE is a unique application. The spreader channel along the north boundary of SGGE is simulated as a reach discharging into a land segment. This is not the conventional direction of flow in the runoff hydrologic cycle. A necessary assumption for representing the spreader channel in this way is that the water from the spreader is spread out evenly over the entire land segment and not along a "line" as in the real physical world.

As SGGE is reflooded, one might assume certain HSPF parameters as infiltration factor (INFILT) and those representing soil storages would be different due to the new nearly saturated or saturated conditions. However, the calibrated parameters are for existing conditions, not for reflooded conditions because the model was not calibrated for the virgin conditions prior to the development of SGGE. In more conventional applications, those alternatives that require straight forward input modifications are easier to analyze. Additionally, looking at specific model output for alternative analysis such as daily surface storage may not represent the physical reality if the runoff flow paths are not correctly represented in the model.

E. OVERALL COMPLEXITY OF MODELING SGGE

The SGGE hydrologic regime is complex in that there is strong interactions between the surface runoff processes, and groundwater table levels, areas of surface inundation, and even canal water levels. The hydraulics in the canals are influenced by backwater effects, unrecorded structural and canal alterations, well pumpage, and adjacent groundwater levels. The modeling of these complexities were inadequate due to the limitations of the current version of HSPF in representing unique South Florida hydrologic conditions such as the overland runoff and infiltration components for high groundwater table.

V. ASSESSMENT OF HYDROLOGIC CONDITIONS FOR THE SGGE REGION

Based on the detailed investigation and modeling of the SGGE region, the following observations of the existing hydrologic conditions were made:

1. The canals largely control the present hydrology of SGGE. Any sheetflow that exists is quickly intercepted by a swale and directed to one of the four main canals. During the dry season, the canals collect groundwater from the adjacent land and discharge it into the Gulf of Mexico. The average discharge from the Faka Union Canal at the outlet of the basin is 250 cfs with average wet season flows over 600 cfs. Using a drainage area of 189 square miles, the runoff amounts to 18 inches per year.

2. The changing vegetation pattern, field observations (Swayze and McPherson, 1977), and studies by Black, Crow and Eidsness and Flora C. Wang have shown a gradual lowering of the groundwater table.

3. A surficial groundwater movement vector, based on three-dimensional finite difference modeling of western Collier County, is illustrated in Figure 6. The surficial groundwater flows are in an east to west direction into the Faka Union Canal both at a location just east of the north Faka Union Canal near Stumpy Strand and also just east of the Faka Union Canal between weirs No. 2 and 3. Additionally, groundwater flows from the western portion of the Fakahatchee Strand State Preserve into the Prairie Canal. These surficial groundwater flow directions vary seasonally. During the wet season when the groundwater levels are high, the flow patterns are in a south to southwest direction. As dry season progresses, the groundwater movement shifts direction to an east-west pattern, draining directly into one of the north-south canals.

4. As the dry season approaches it appears the groundwater flow at Faka Union Canal near weir No. 1 recedes at a faster rate during the early years (1970 to 1975) after the

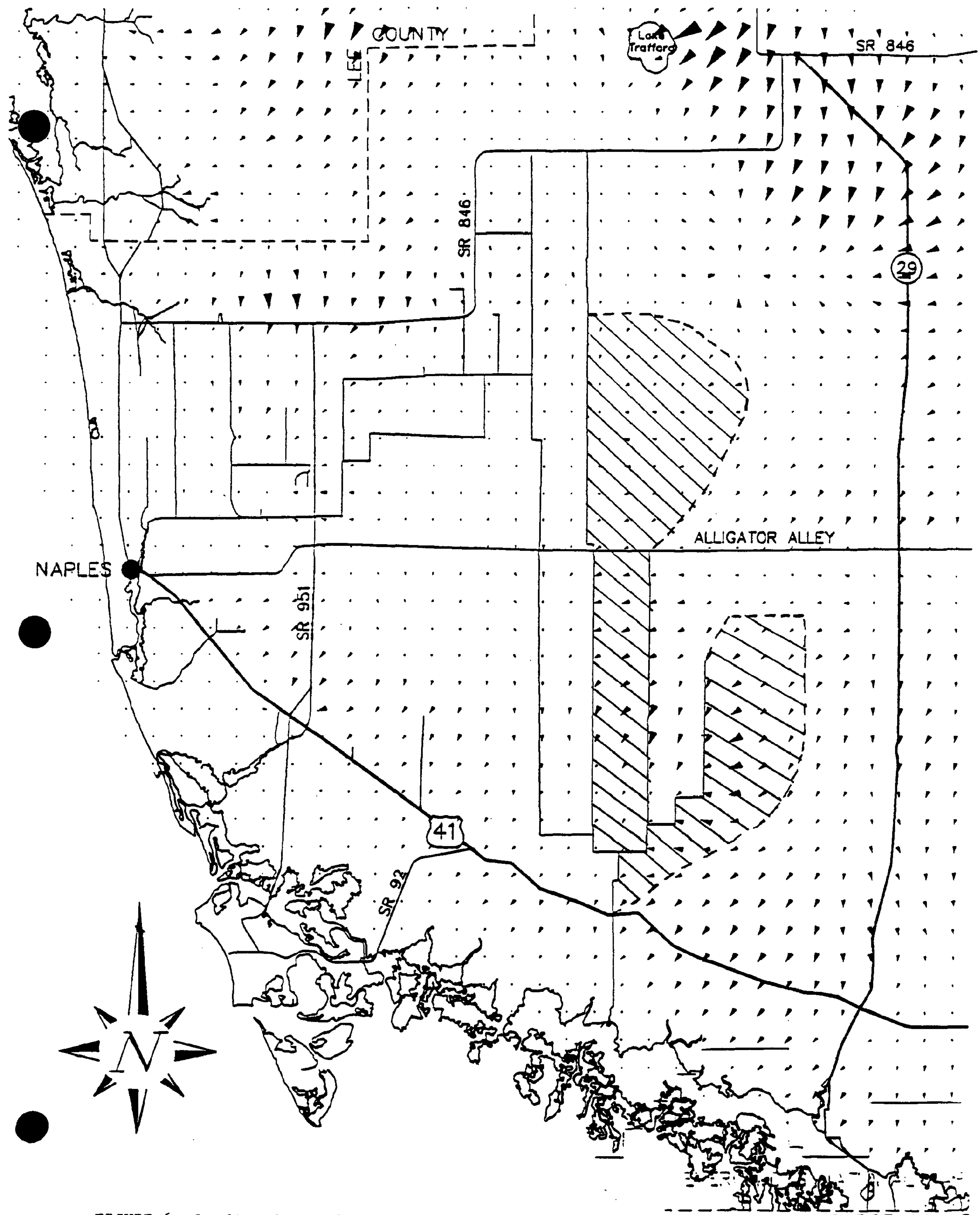


FIGURE 6. Surficial Aquifer Horizontal Movement During Dry Season
(Bennett, Michael W., April 1992)

canals were built than later years (1976 to 1984). This indicates that the construction of the canals not only increases surface runoff, but increases the rate of groundwater outflow, perhaps causing groundwater "peaks" that were not present before the canals were built.

5. Better calibration results were obtained at Faka Union No. 5 when a higher value for deep fraction (DEEPFR) was used. DEEPFR represents the fraction of groundwater lost to the deep aquifer but also could represent groundwater lost to wellfield pumpage. This indicates that the City of Naples wellfield located between Weirs No. 5 and 4 is reducing groundwater outflow from the surficial aquifer north of Faka Union Weir No. 5.

VI. DEVELOPMENT OF ALTERNATIVE RESTORATION PLANS

A. CRITERIA FOR PLAN DEVELOPMENT

Alternative structural measures to modify the existing water management system of SGGE were evaluated on the ability to meet the following study objectives:

1. Wetland hydroperiod restoration,
2. Surface water sheetflow restoration,
3. Replacement of concentrated shock load discharges to estuaries with distributed sheetflow,
4. Improved water storage and aquifer recharge,
5. Enhanced surface water deliveries to Fakahatchee Strand,
6. Reduction of over-drainage of Fakahatchee Strand,
7. Reduction of over-drainage of Panther Refuge lands,
8. Maintenance of existing flood protection for areas north of I-75.

In addition to evaluating the effectiveness of each alternative to accomplish the stated objectives of the project, the economic feasibility and the hydrologic and hydraulic impacts were evaluated.

In order to quantify the system's response with respect to the hydrologic and hydraulic evaluation of the alternatives, various model outputs were analyzed. The various storage zones (upper zone soil, lower zone soil and groundwater storage) were analyzed. Also considered were the runoff volumes at Faka Union Weir No. 1 and over the entire basin. The base conditions to which the alternatives were compared was the current system for which the model is calibrated. A 23-year simulation was run (1970-1992) for both the base conditions and the alternatives.

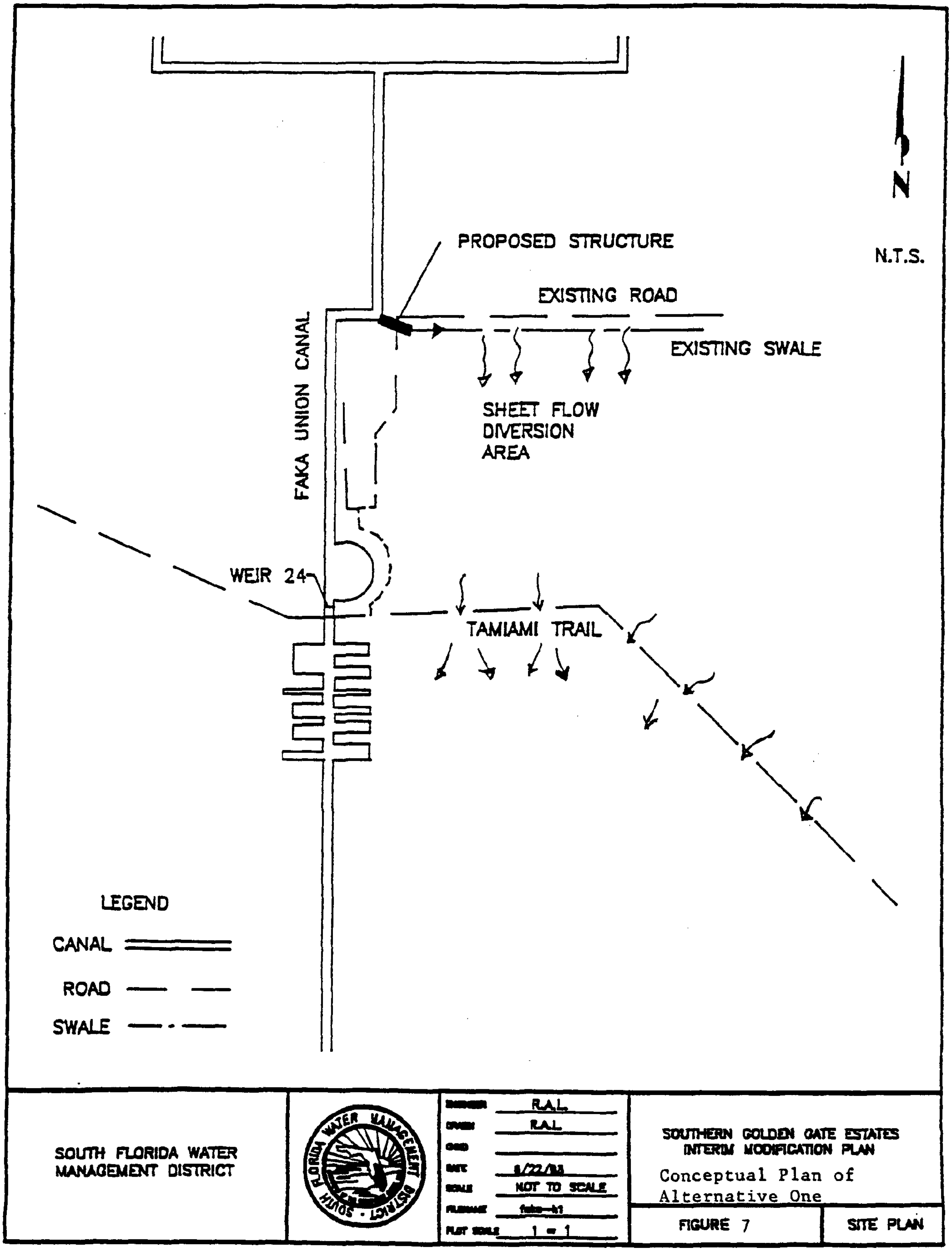
B. IDENTIFICATION OF ALTERNATIVES

Within the purview of the developed hydrologic-hydraulic model three alternative restoration measures were formulated to accomplish the stated objectives of the project.

1) Alternative 1: Diversion Structure Plan. This alternative considers the present interim plan proposed by the Big Cypress Basin to be implemented in FY 1995. This is a partial plan, and not expected to achieve the full range of objectives identified for the SGGE restoration project. It includes a flow diversion structure with three 48-inch gated culverts located approximately one mile north of Faka Union Weir No. 1 (see Figure 7). The culverts will divert approximately 50 percent of the existing base flow to a spreader channel. The dissipated flows will be conveyed through public lands owned by the Fakahatchee Strand State Preserve (Florida Department of Environmental Protection) to distribute through the bridges under U. S. 41. These diverted flows will be dissipated and filtered through wet prairies as sheetflows to the Faka Union Bay.

2) Alternative 2: Spreader Channel and Canal/Road Removal Plan. This alternative (as shown in Figure 8) considers a spreader channel immediately below I-75 extending from the western boundary of the SGGE study area near the western boundary of the Fakahatchee Strand State Preserve. This plan also considers removal of all roads and canals south of Alligator Alley. This alternative is intended to provide insight to predevelopment conditions had there been no development south of the Alley, although canal and roads will continue to exist north of the alley. Major system response information for SGGE such as runoff volumes and rates and relative soil storages were examined. Evaluation of northern Golden Gate Estates runoff was part of the output analyzed in this alternative.

3) Alternative 3: Spreader Channel, Canal Blocks and Selected Road Removal Plan. This alternative has several elements. It includes two spreader channels with pump stations,


N
N.T.S.
PROPOSED STRUCTURE
EXISTING ROAD
EXISTING SWALE
FAKA UNION CANAL
SHEET FLOW
DIVERSION
AREA
WEIR 24
TAMIAMI TRAIL
LEGEND
CANAL
ROAD
SWALE
SOUTH FLORIDA WATER
MANAGEMENT DISTRICT
SOUTH FLORIDA WATER MANAGEMENT DISTRICT
R.A.L.
R.A.L.
NOT TO SCALE
1 = 1
SOUTHERN GOLDEN GATE ESTATES
INTERIM MODIFICATION PLAN
Conceptual Plan of
Alternative One
FIGURE 7
SITE PLAN

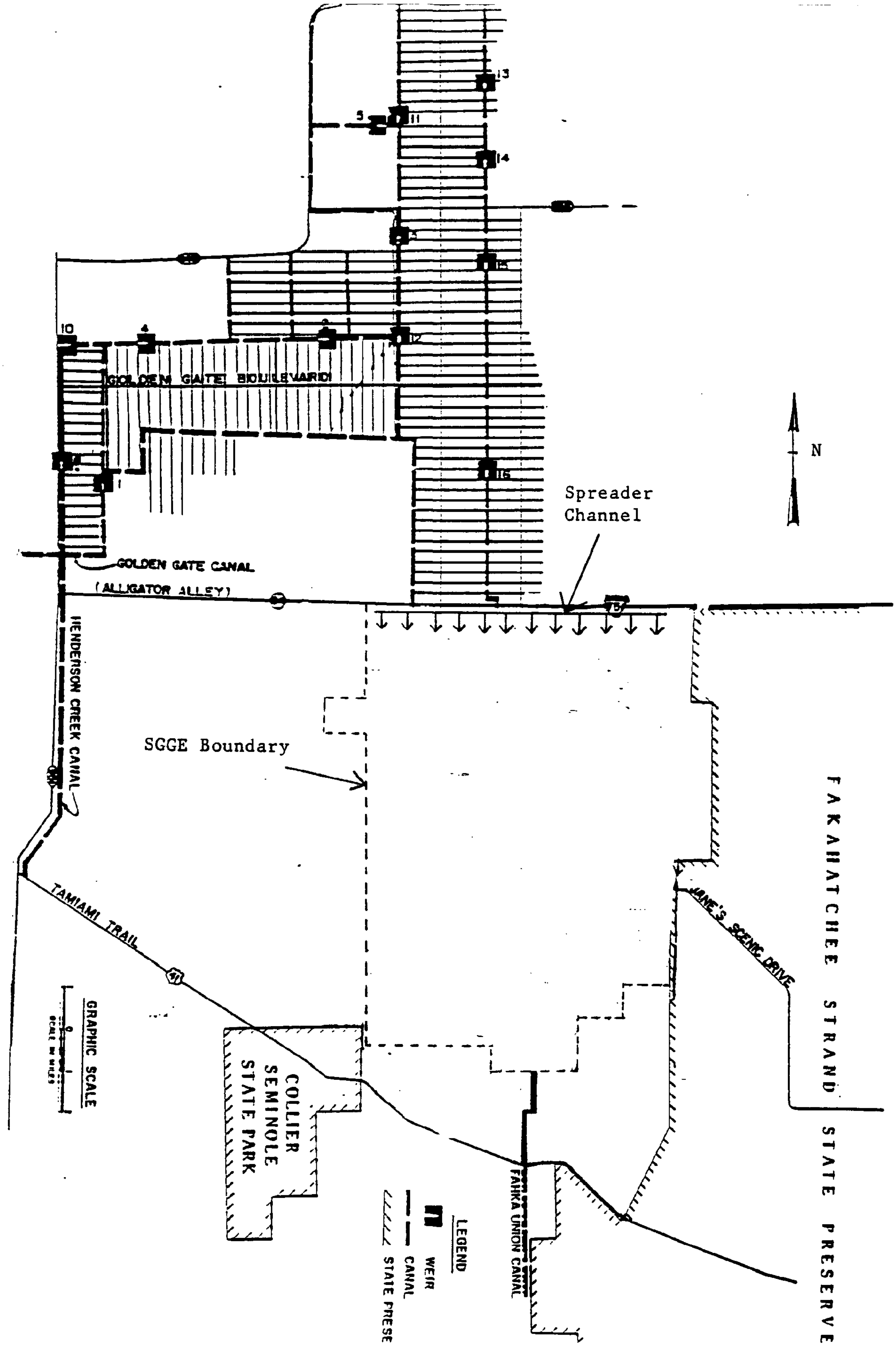


FIGURE 8. Conceptual Plan of Alternative Two

removal of selected roads, canal plugs, and drainage improvements to Miller Boulevard for better exchanges of flow under the road (see Figure 9).

a) <u>Spreader Channels</u>

The first or main spreader channel would extend eastward from Everglades Boulevard to approximately one and one-half miles east of Merritt Canal. The inflow to this canal would be discharge from the Faka Union Canal and the north Merritt Canal. The spreader would be located just down from the proposed weir structure on the Merritt Canal which is approximately 200 feet south of I-75 (see Figure 10). The Faka Union Canal would be widened before discharging into the spreader to reduce the velocities in the canal before reaching the spreader.

The purpose of the spreader channel is twofold. First, it must take flow from the two north-south canals (Faka Union and Merritt) and spread this flow in an east-west direction. Secondly, it must allow discharge to the south onto the land surface. If only the first purpose was important, a channel cross-section similar to the current GAC canals could be used. However, raising the water surface elevation in the spreader channel high enough to allow overtopping and discharge onto the land surface (average elevation 11.5 feet NGVD), would compromise flood protection for the upstream portions of the Faka Union Canal. Two possible configurations for the spreader channel that would maintain flood protection north of I-75 are proposed:

1) The cross-section of the spreader channel would be similar to the existing GAC canals. The main goal of the canal would be to convey the flows in an east-west direction. The canal stages both in the Faka Union Canal and in the spreader channel would be maintained to prevent flooding north of I-75. The water in the spreader channel would then be pumped from the spreader onto the land surface as shown in Figure 11.

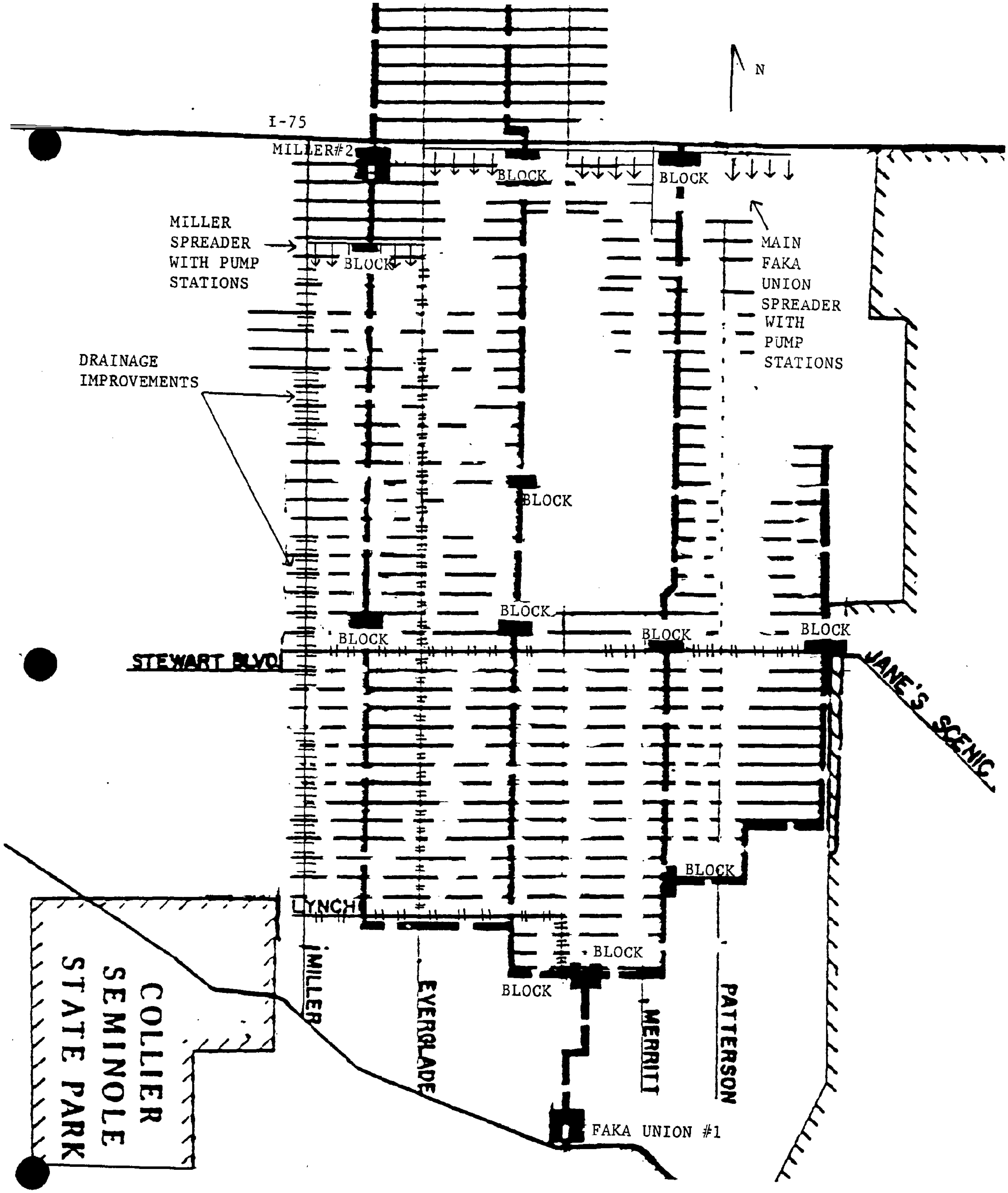
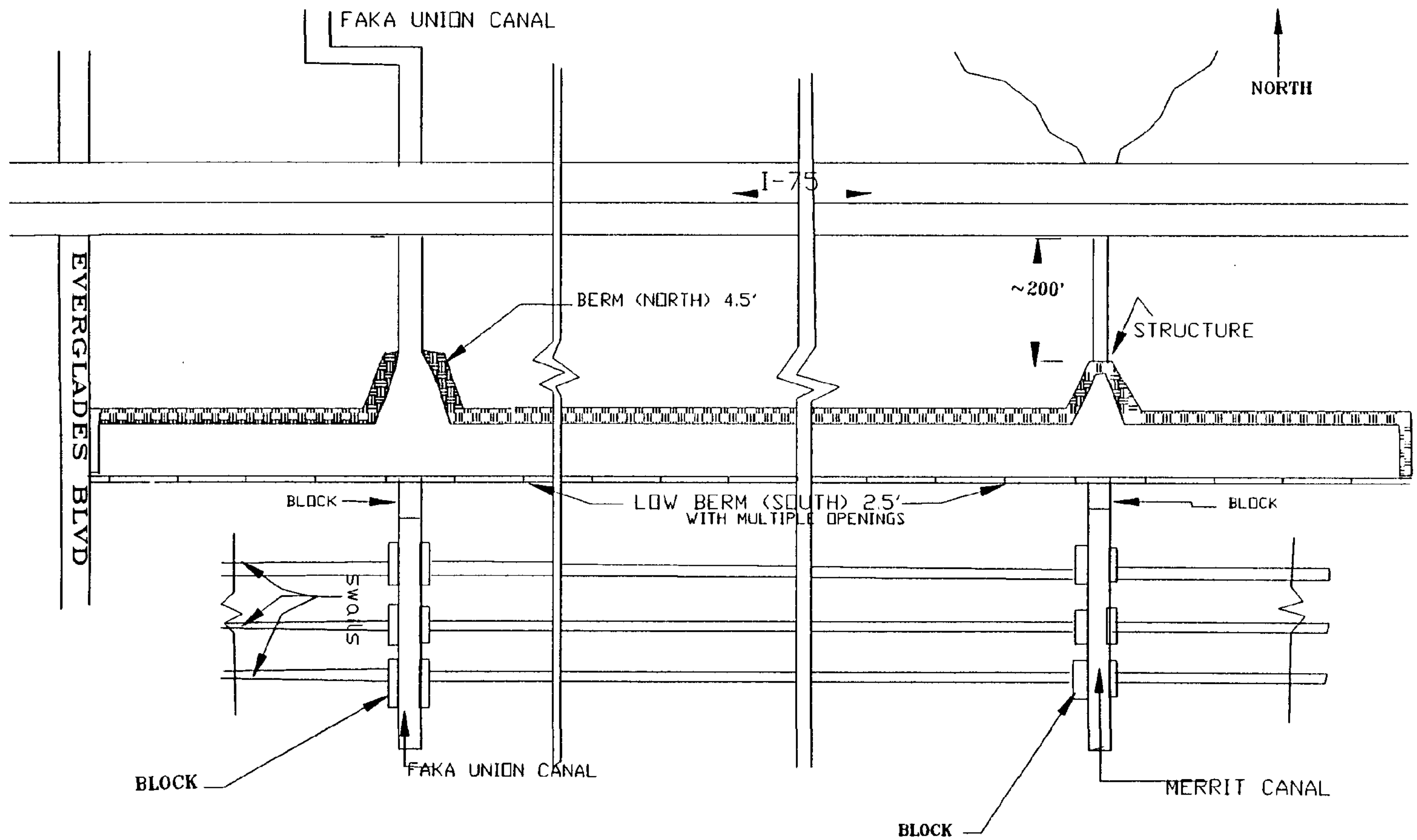


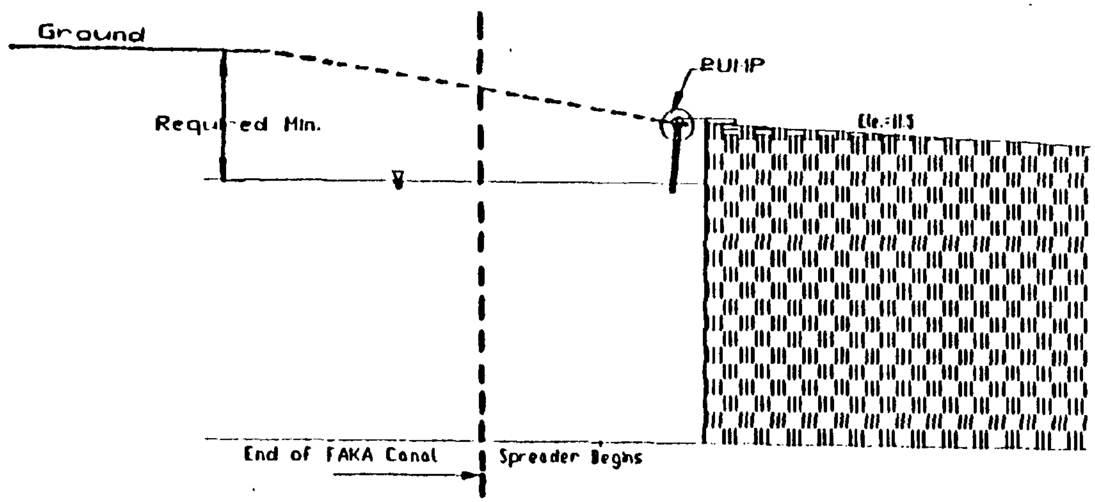
FIGURE 9. Conceptual Plan of Alternative Three



CONCEPTUAL PLAN OF SPREADER CHANNEL AND CANAL/SWALE BLOCKS – PLAN VIEW

NOT TO SCALE

FIGURE 10



SPREADER CHANNEL CROSS-SECTION

FIGURE 11

The exact number and location of the pumps would be limited by the economic feasibility. However a minimum of three locations have been identified for the Faka Union Spreader and two locations for the Miller Spreader which correspond to the headwaters of major flowways and are shown in Figure 12. The first is just east of Everglades Boulevard, the second is near Desoto Boulevard and the third is near the Merritt canal. The pump stations for the Miller Spreader would be located on each side of the canal. There would be the flexibility to direct more or less flow into any desired flowway through the operation of the pumps.

2) The second configuration for the spreader channel is shown in Figure 13.

This plan requires an installation of a canal block that allows two water surface elevations to be maintained on either side of the spreader channel. The water surface elevation would be "stepped up" by pumping into the spreader channel and the water would then flow by gravity onto the land surface. The low berm on the downstream side would have several openings (i.e. notches or culvert pipes) that could be evenly spaced or alternatively spaced to allow more discharge into the headwaters of the flowways (see Figure 14). The purpose of the low berm would be to force the water movement in an east-west direction and allow greater spreading capability and possibly prevent a situation where the majority of the water is discharged at or near the Faka Union Canal. The spreader channel would be a relatively wide and shallow canal with a berm on the north side to prevent water from escaping north. The canal outflow would distribute evenly over the entire area rather than at only the three places as in the first configuration. This second configuration would not allow the flexibility to direct more water into a particular flowway. Both configurations were represented in HSPF the same way. Further explanation on incorporating the effect of the alternatives in the model is explained in the next section.

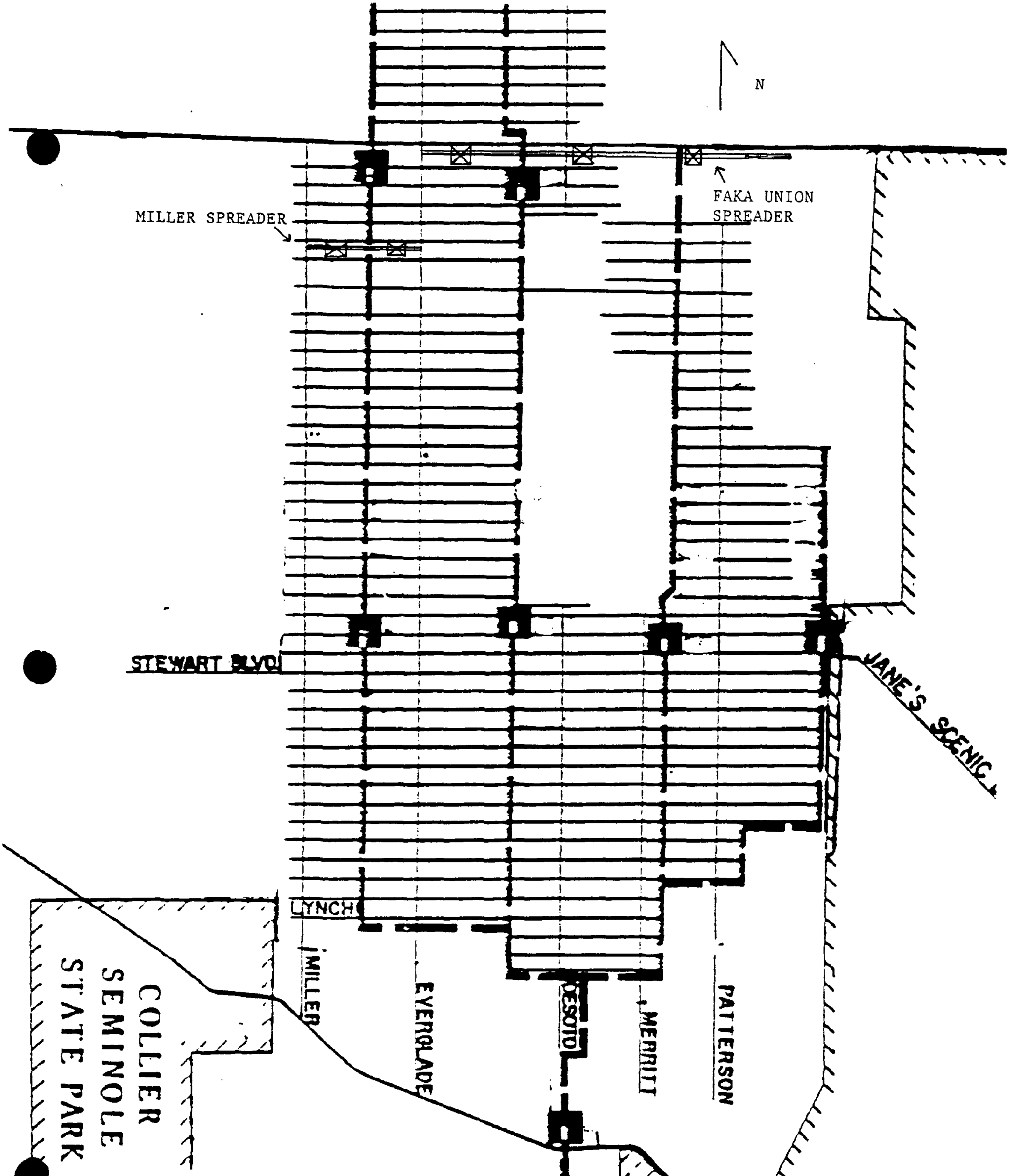
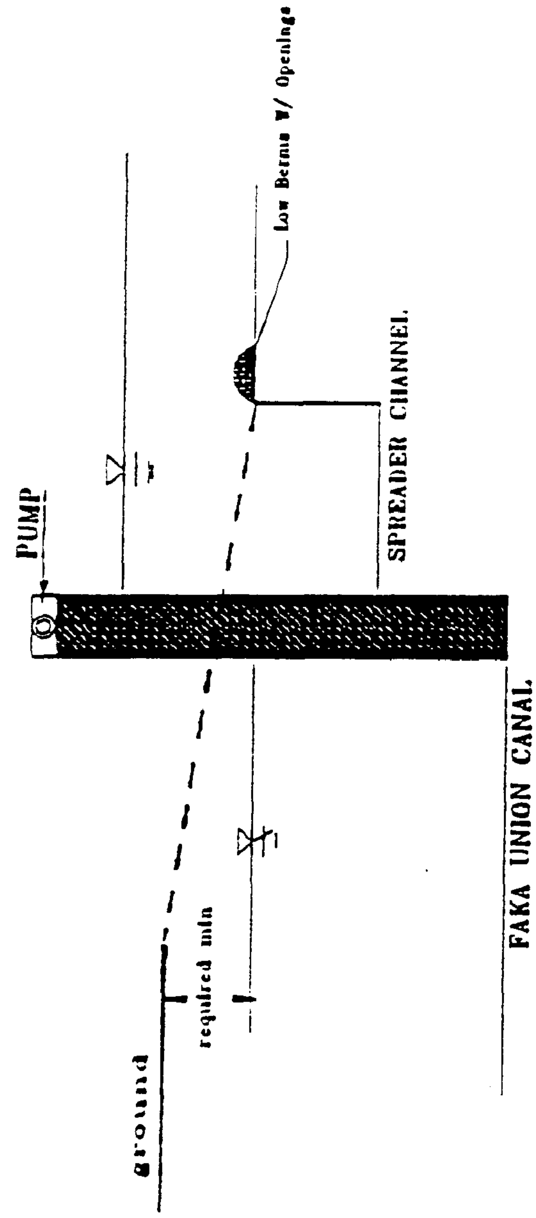


FIGURE 12. Pump Locations



SPREADER CHANNEL CROSS-SECTION

FIGURE 13

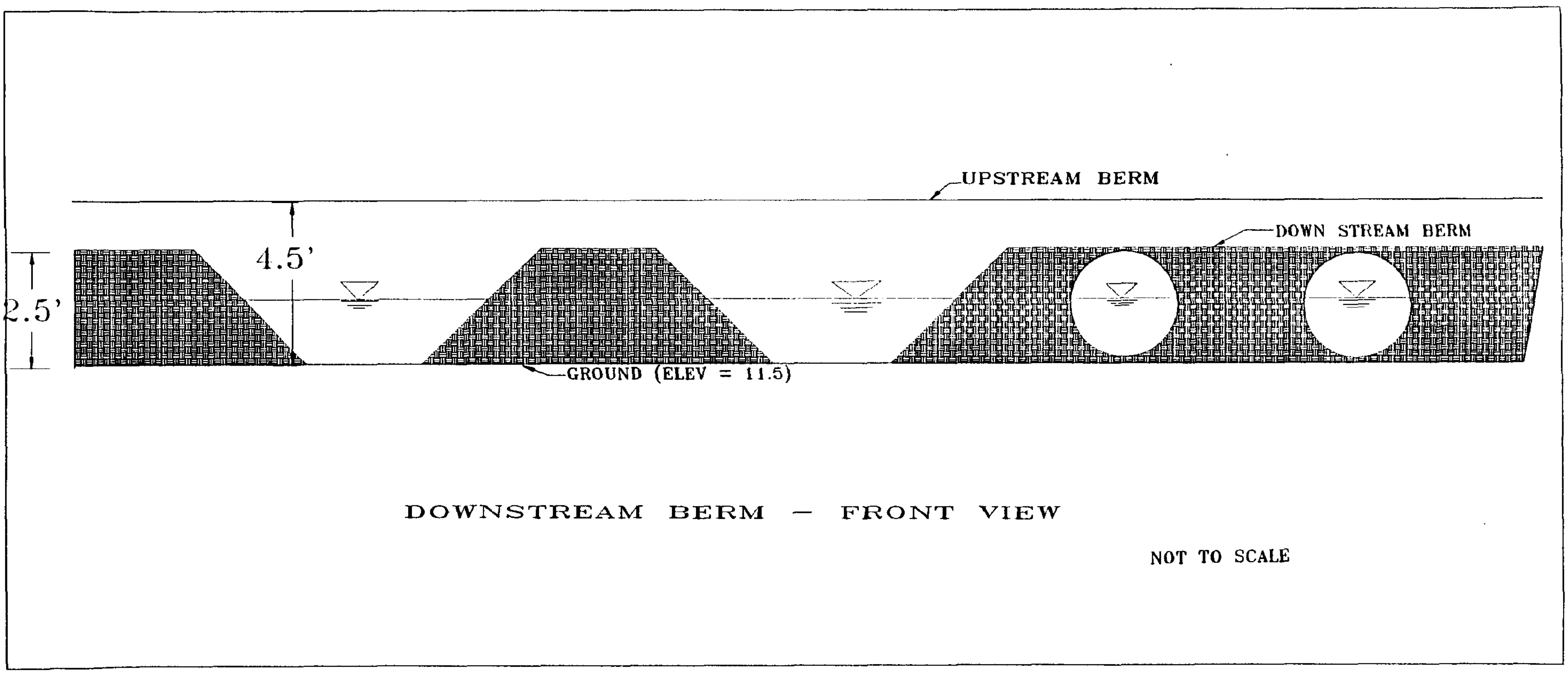

UPSTREAM BERM
DOWN STREAM BERM
4.5'
2.5'
GROUND (ELEV = 11.5)
DOWNSTREAM BERM – FRONT VIEW
NOT TO SCALE

FIGURE 14

The second spreader channel would collect outflows from the Miller Canal and would extend from the western boundary of SGGE to Everglades Boulevard, approximately one and a quarter miles south of I-75. Several upland areas exist just south of I-75 within a mile of Miller Canal. Locating the spreader farther south would prevent water from circumventing the islands and backing up to the west. The alternative designs for the Miller spreader channel would be similar to the design for the main Faka Union spreader channel described above, but smaller to accommodated less flow.

b) Road Removal

Given that there are approximately 290 miles of roads in SGGE, their complete removal is not economically feasible. The major factors considered to select the segments of road for removal were: (a) roads that intercepted major flowways, (b) roads located at the north end of SGGE or closest to the spreader channels and (c) roads having the greatest environmental impact. The major flowways were determined using information from topographical maps, soils and vegetation maps, areal photographs, satellite images and field inspections. The roads crossing major flowways were considered top priority for removal. By removing roads at the north end first will ensure a flowway from the spreader channels and will prevent any backing up of water. As the water flows south, and farther from Interstate 75, the impact from any damming effect of roads is reduced. The paved roads in the SGGE area are wider and generally higher than the side dirt roads. Many of these dirt roads are overgrown with vegetation and are now merely a narrow path. Therefore, paved roads were considered to have a greater impact on the environment. Figure 9 shows the road segments selected for removal.

c) Canal Plugs

The canals in the SGGE have been responsible for the overall degradation of the hydrology and ecology of the area, much more so than the roads. Therefore, elimination of channelized flow south of I-75 is suggested. With the removal of channelized flow south of I-75, any spreader channels north of 41 or off of the Merritt or Prairie canals would be impractical due to lack of inflow into the spreader channel. Therefore, restoration elements of that type are not considered in this alternative. Several canal plugs are suggested and illustrated in Figure 15.

Plugs B5, B1 and A3 would be south of the spreader channels and prevent water from draining from the spreader directly into the canals. Since the canals are several miles long, they could provide some localized drainage, especially early in the wet season when canal stages are low. Therefore, the remaining canal blocks spaced at fairly regular intervals prevent any drainage from occurring. Plugs A1 through A5 could be a first phase of restoration and B1 through B6 could be constructed as additional land is acquired by the state. If funding permits, blocking the swales at the end where they enter the canals would prevent localized drainage. Additionally, the spoil banks on the sides of the canals, particularly near the south end of the canal system, need to be removed to allow flow across the canals.

d) Drainage Improvements

If Miller Boulevard were to become an evacuation route, several additional culverts or other cross-drainage facilities would need to be placed to provide adequate exchange of flow under the road. Everglades Boulevard, Stewart Boulevard and part of Lynch Boulevard remain intact for access to SGGE, however cross-drainage facilities would have to be improved for these roads. It is to be noted that during the wet season, under restored conditions, these roads may be under water.

C. HYDROLOGIC AND HYDRAULIC SIMULATION OF ALTERNATIVES

The hydraulic configuration of the above three structural alternatives was formulated in the RCHRES module of the calibrated HSPF model of SGGE and their performance was simulated for the entire period of simulation. The detailed evaluation of alternatives are

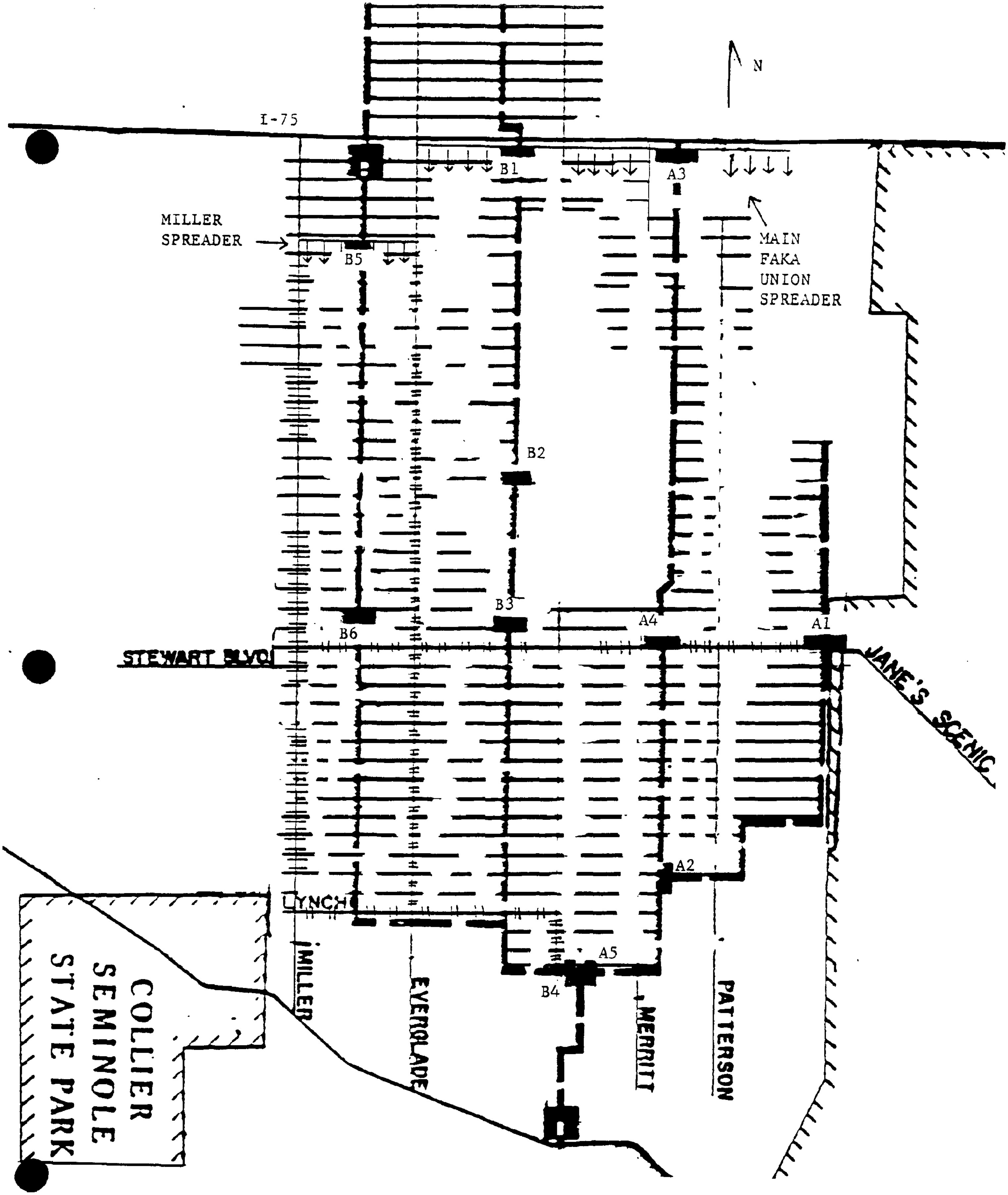


FIGURE 15. Canal Plugs

described below.

Alternative one was represented in HSPF by creating a new reach for the spreader channel and having this reach discharge into a land segment as a surface lateral inflow. However, because the receiving land area was too small an area, program complications prevented output analysis of this alternative as regards to the effects on soil storages, and hydroperiods of the overall basin.

The major model input to represent alternative two was changed by simulating the main spreader channel as a RCHRES and routing the outflow to a pervious land segment (PLS). As no further RCHRES was considered thereafter, the simulation for the downstream segments was performed only by the PERLND module. The runoff from the land segments was routed from one PLS to another, according to historical drainage patterns, as a surface, interflow and groundwater lateral inflows, until the runoff left the boundary of the basin.

The system representation was also changed to represent alternative three. Two new reaches were created to represent the spreader channels and these reaches discharged into the land segments directly to the south. The runoff from the land segments was then routed through historical drainage ways which were represented by newly created reaches as wide and shallow channels. The plugged canals were represented more like "ponds" in the model with interconnection occurring only when one pond overflows to another as water surface rises above the crest of the canal plugs.

VII. EVALUATION OF ALTERNATIVE PLANS

A. HYDROLOGIC PERFORMANCE OF ALTERNATIVE ONE

Alternative one is a partial plan and does not achieve all the objectives of the project. The limited scope of this alternative provides a reduction in point source discharge of approximately 50 percent of the existing Faka Union Canal baseflow at the outlet. The sheetflow created would enhance the adjacent wetlands and reduce the freshwater shock loads to the estuary. However, due to program complications the specific relative changes in soil storages and hydroperiods over the entire basin could not be examined.

B. HYDROLOGIC PERFORMANCE OF ALTERNATIVE TWO

The overall water budget for alternatives two and three relative to the existing conditions is illustrated in Table 2.

The runoff is significantly reduced for alternatives two and three. Without the canals intercepting the shallow aquifer, groundwater does not contribute to runoff; hence overall runoff is reduced. The discharge at Faka Union Weir No. 1 is not applicable for alternative two because it is assumed no canals exist south of I-75.

Figures 16 through 27 show the average daily soil storages in the upper and lower soil zones and active groundwater storages for existing and alternative two conditions for those land segments south of I-75 for each month of the simulated period from January 1970 to December 1992. Average daily upper zone soil storage increased by ten percent, lower zone by six percent and active groundwater storage increased 205 percent. The active groundwater storages for alternative two were extended annually for an average one to two-month period longer over the existing threshold conditions.

TABLE 2

SIMULATED WATER BUDGET FOR
EXISTING CONDITIONS
AND ALTERNATIVES TWO AND THREE

	Existing Conditions	Alternative No. Two	Alternative No. Three
Inflow			
Precipitation (in)	59.72	59.01	59.90
Outflows			
Evaporation (in)	36.74	37.65	38.16
Deep Percolation (in)	1.52	1.58	1.58
Sheetflow Runoff (in)	0.06	0.13	0.11
Runoff at Faka Union Weir No. 1 (in)	18.50	0	0.56
Active Groundwater Flow (in)	2.97	19.84	19.84

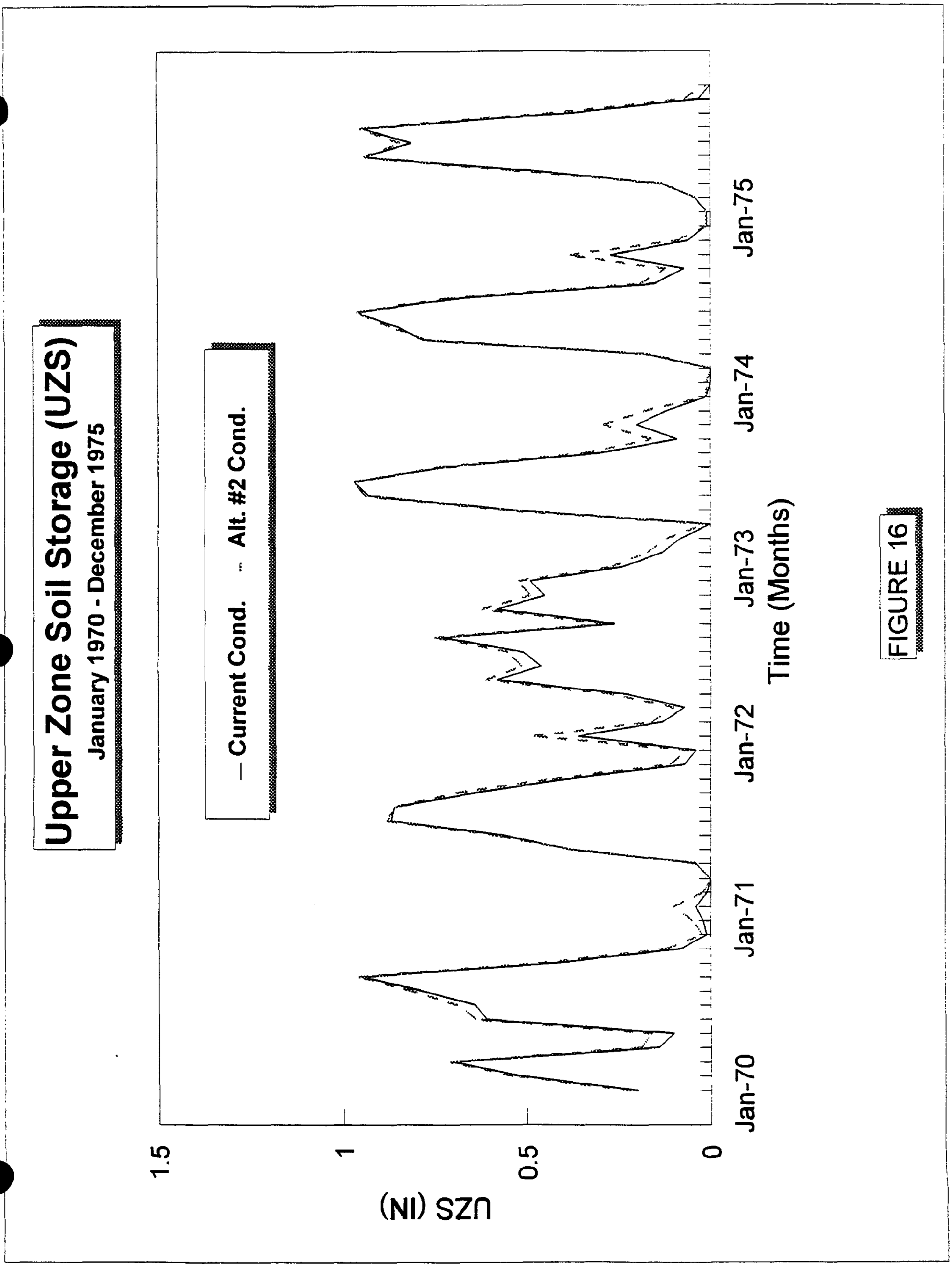

Upper Zone Soil Storage (UZS)
January 1970 - December 1975
Current Cond.
Alt. #2 Cond.
UZS (IN)
1.5
1
0.5
0
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)

FIGURE 16

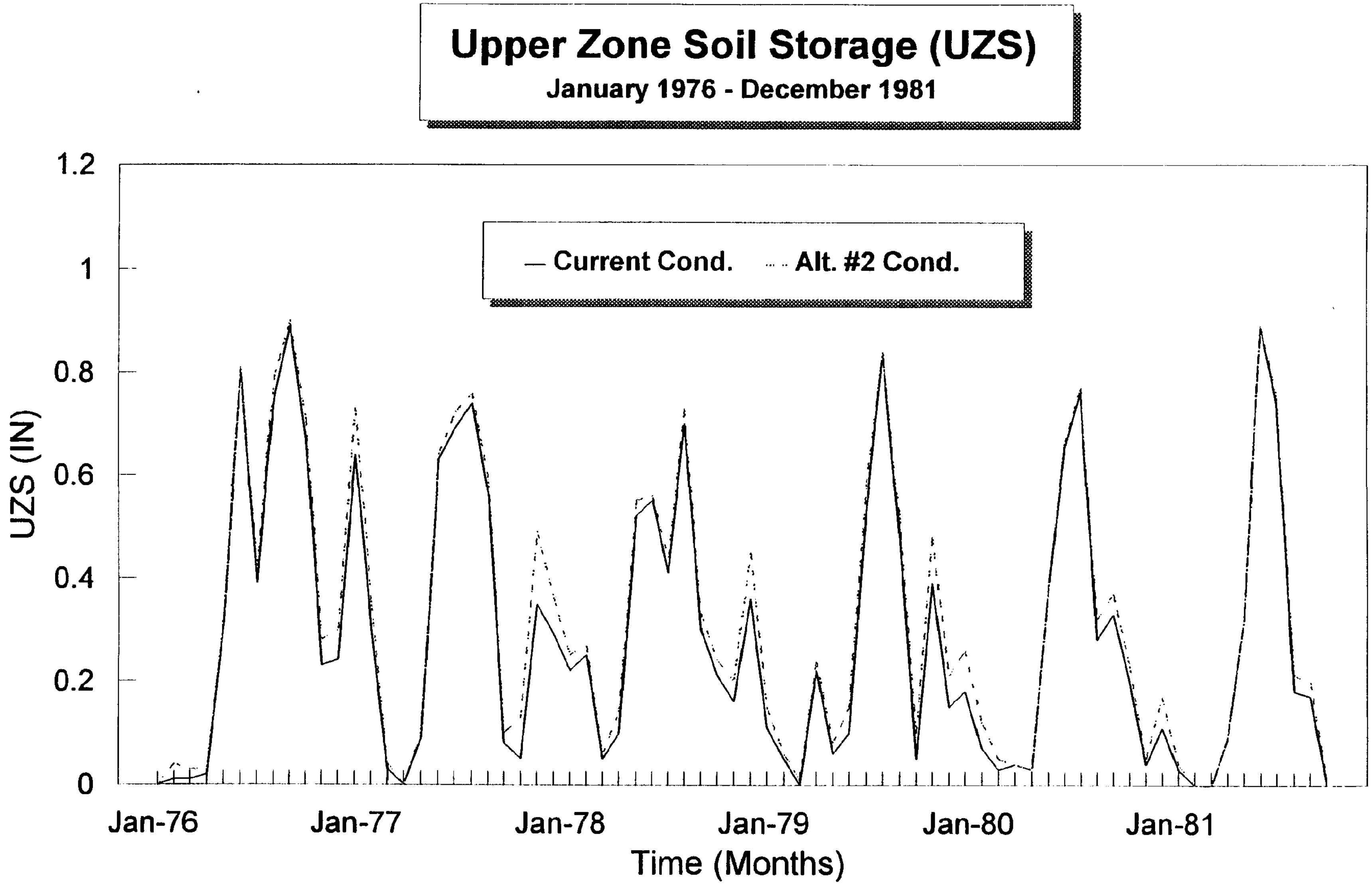
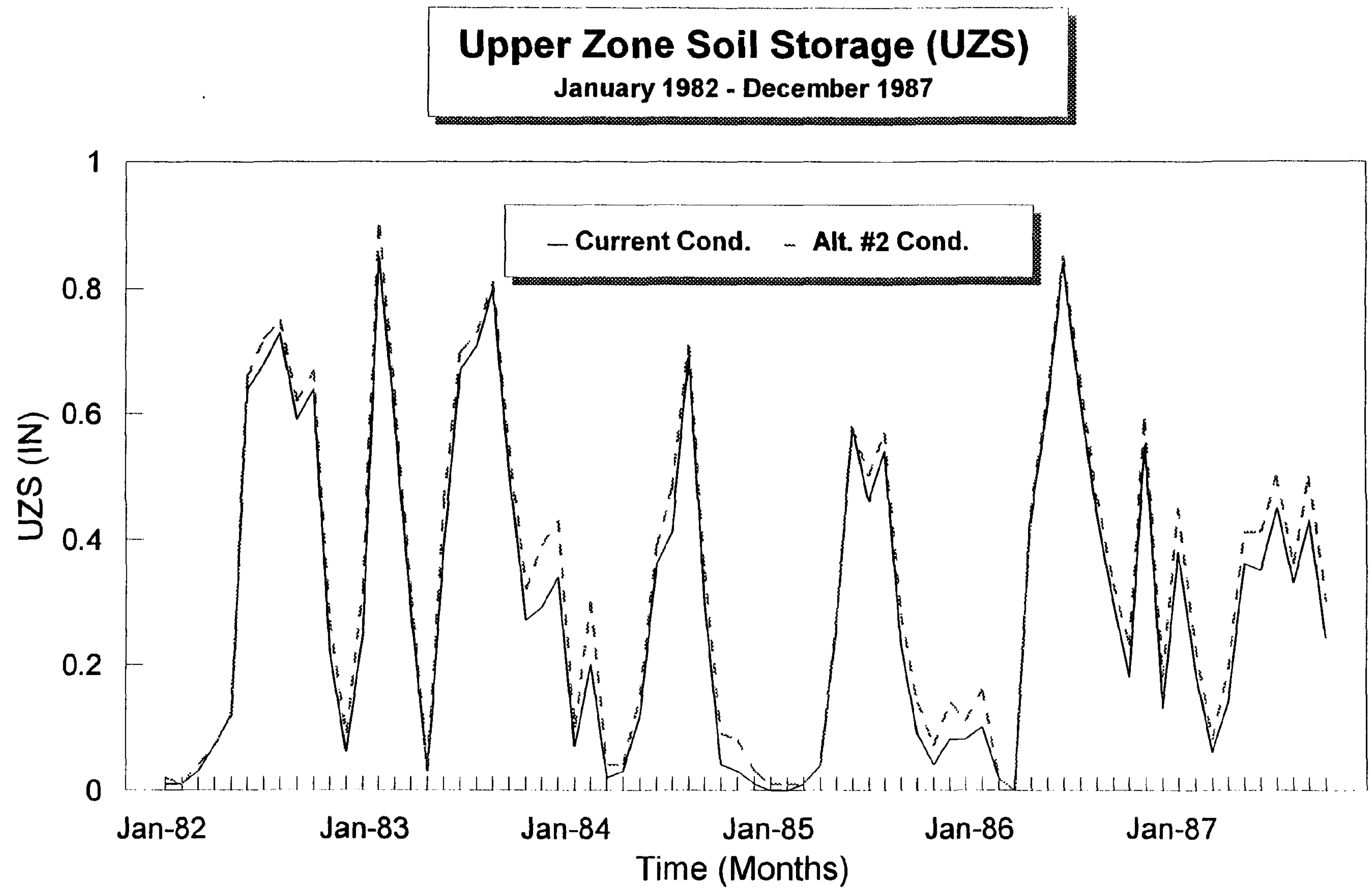

Upper Zone Soil Storage (UZS)
January 1976 - December 1981
Current Cond.
Alt. #2 Cond.
UZS (IN)
1.2
1
0.8
0.6
0.4
0.2
0
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)

FIGURE 17



Upper Zone Soil Storage (UZS)
January 1982 - December 1987
Current Cond.
Alt. #2 Cond.
UZS (IN)
1
0.8
0.6
0.4
0.2
0
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)

FIGURE 18

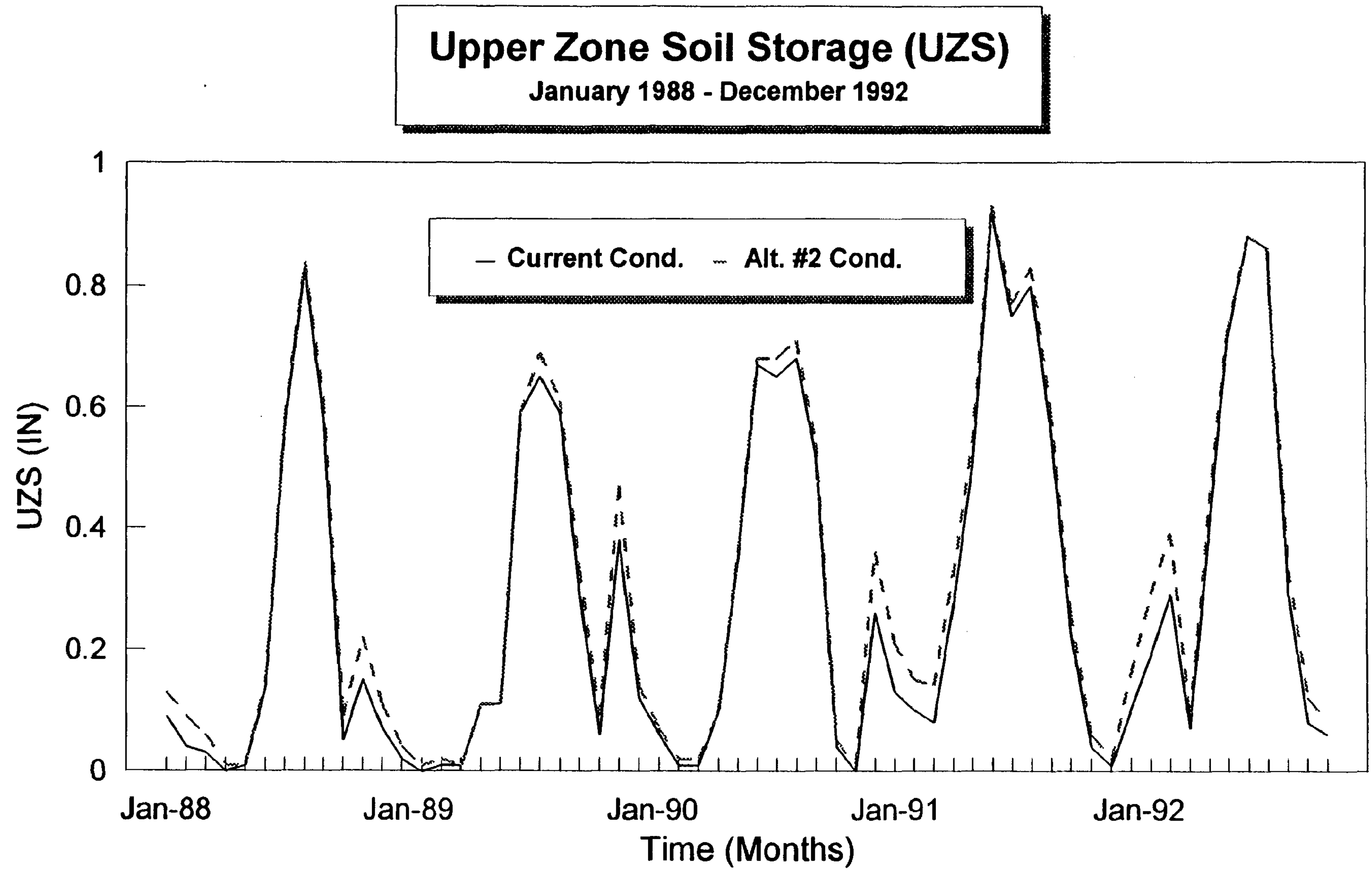

Upper Zone Soil Storage (UZS)
January 1988 - December 1992
— Current Cond.
Alt. #2 Cond.
UZS (IN)
1
0.8
0.6
0.4
0.2
0
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)

FIGURE 19

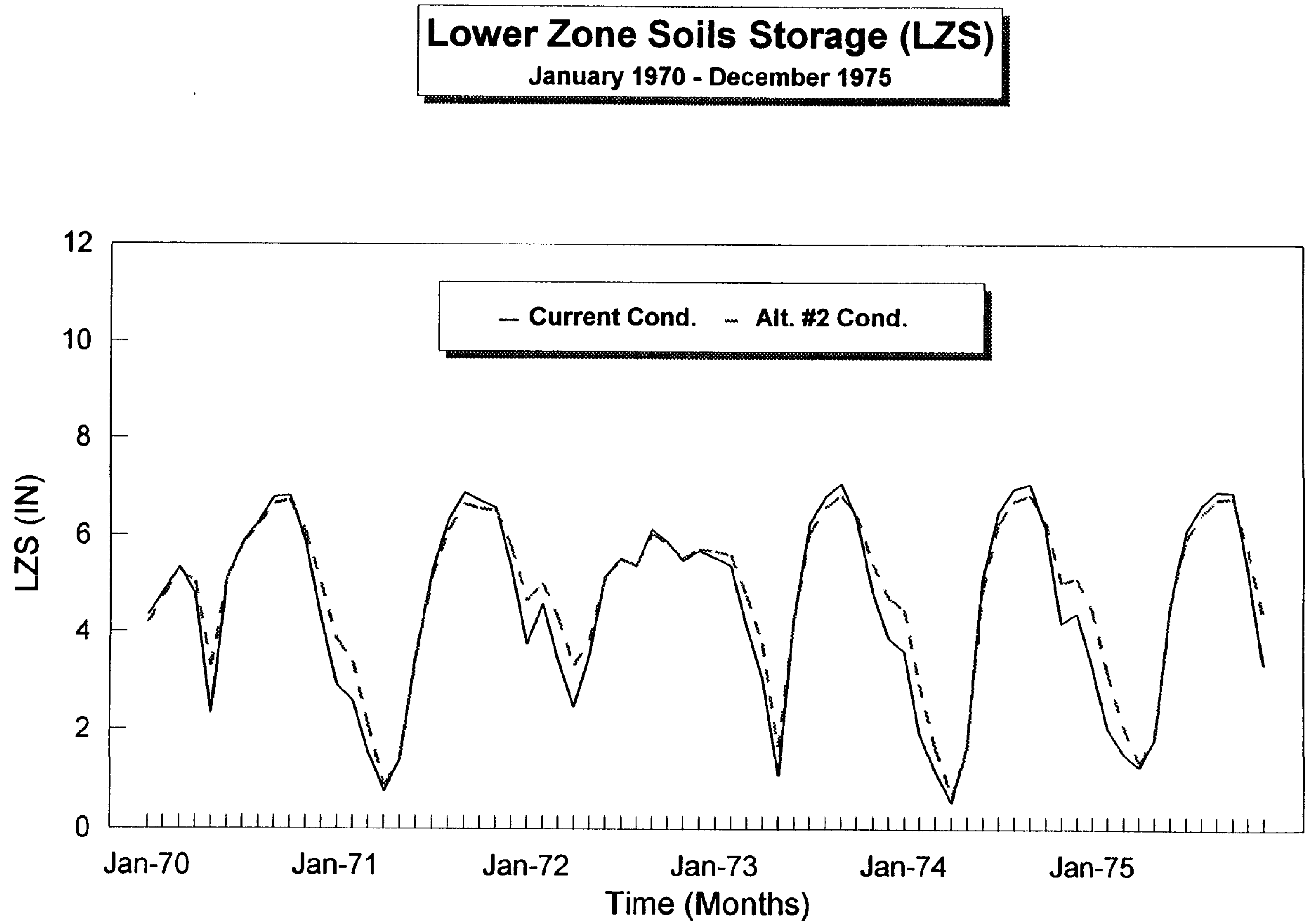
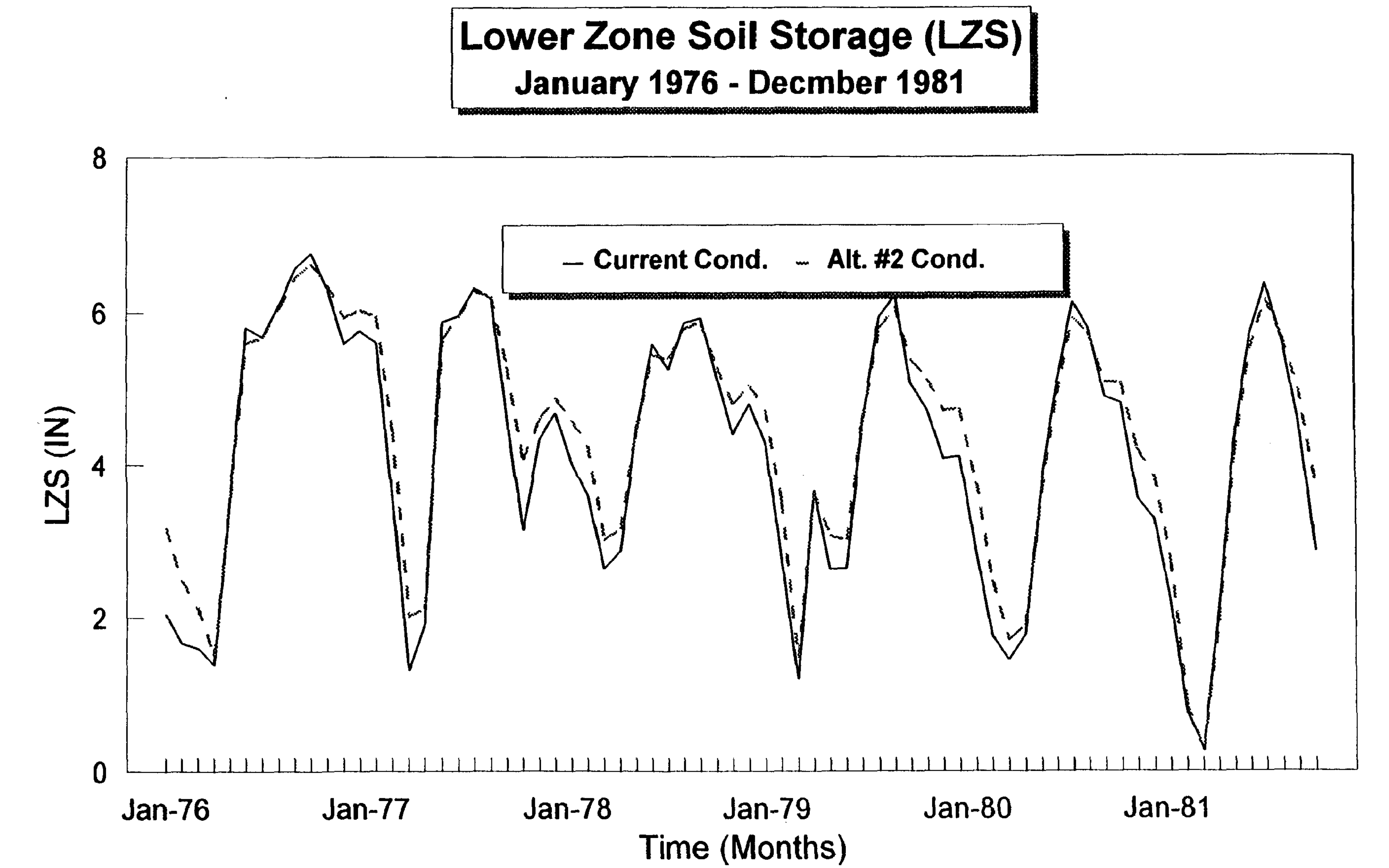

Lower Zone Soils Storage (LZS)
January 1970 - December 1975
— Current Cond.
-- Alt. #2 Cond.
LZS (IN)
12
10
8
6
4
2
0
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)

FIGURE 20



Lower Zone Soil Storage (LZS)
January 1976 - Decmber 1981
— Current Cond.
- Alt. #2 Cond.
LZS (IN)
0
2
4
6
8
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)

FIGURE 21

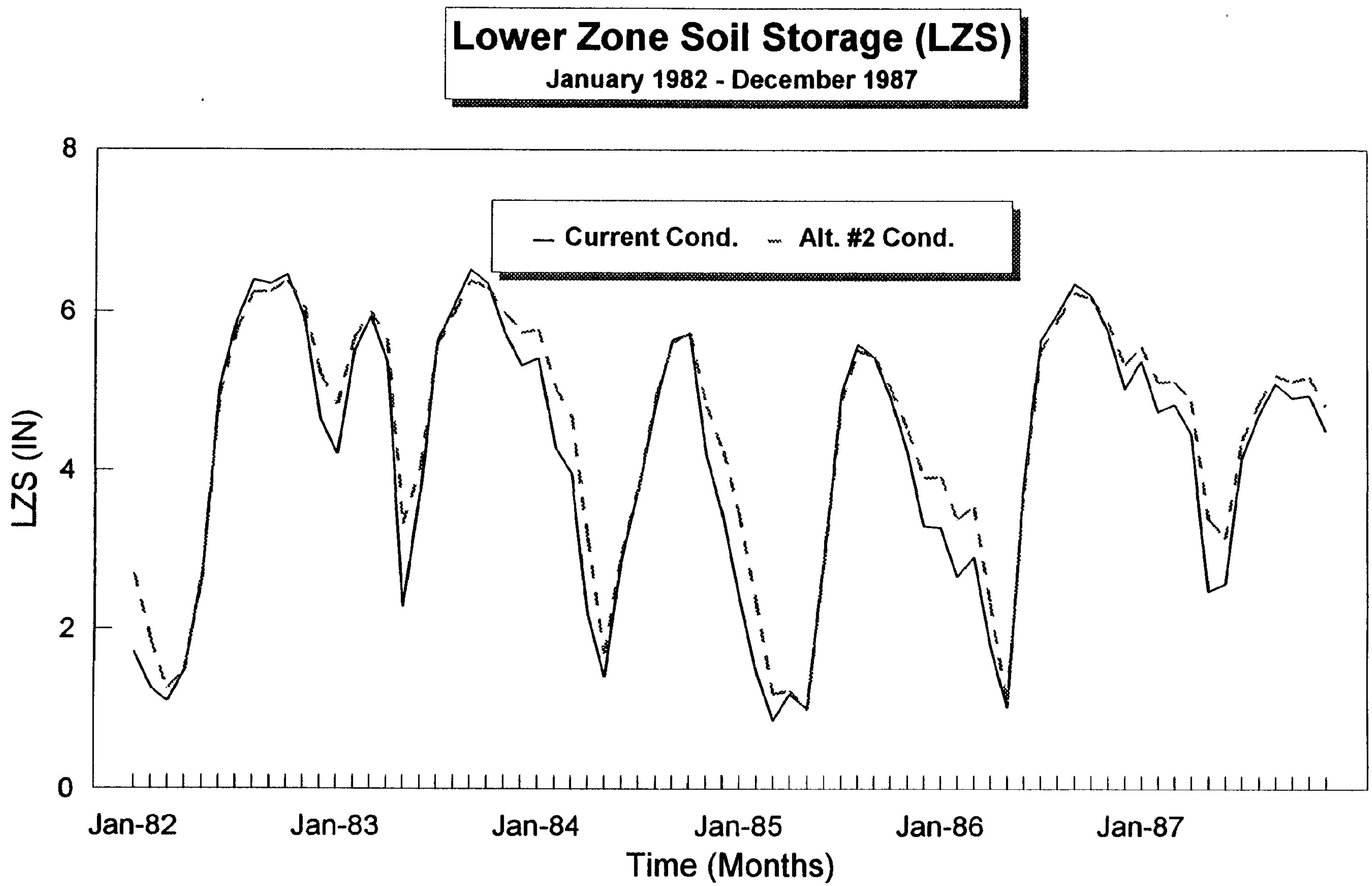

Lower Zone Soil Storage (LZS)
January 1982 - December 1987
— Current Cond.
Alt. #2 Cond.
LZS (IN)
0
2
4
6
8
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)

FIGURE 22

Lower Zone Soil Storage (LZS)

January 1988 - December 1992

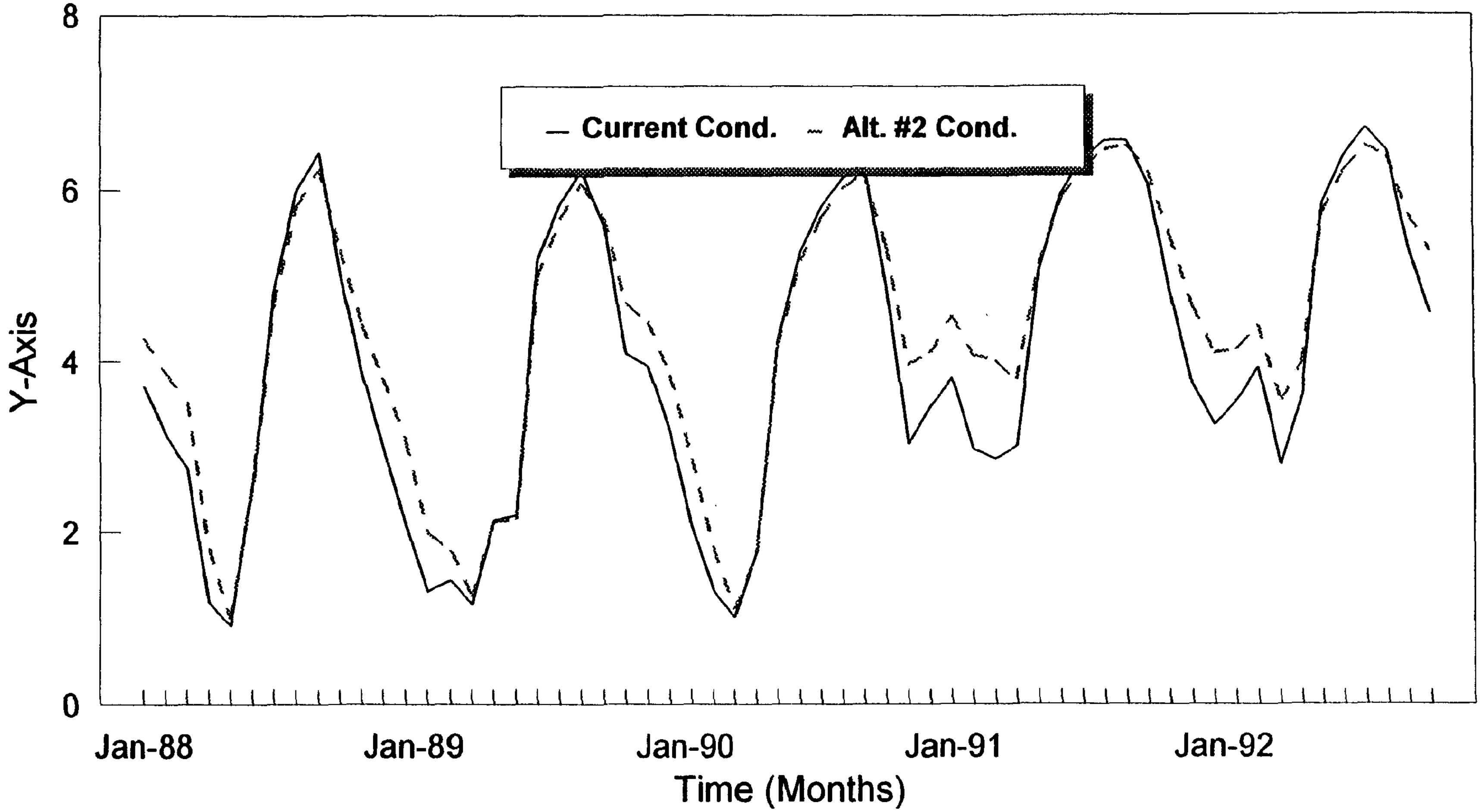
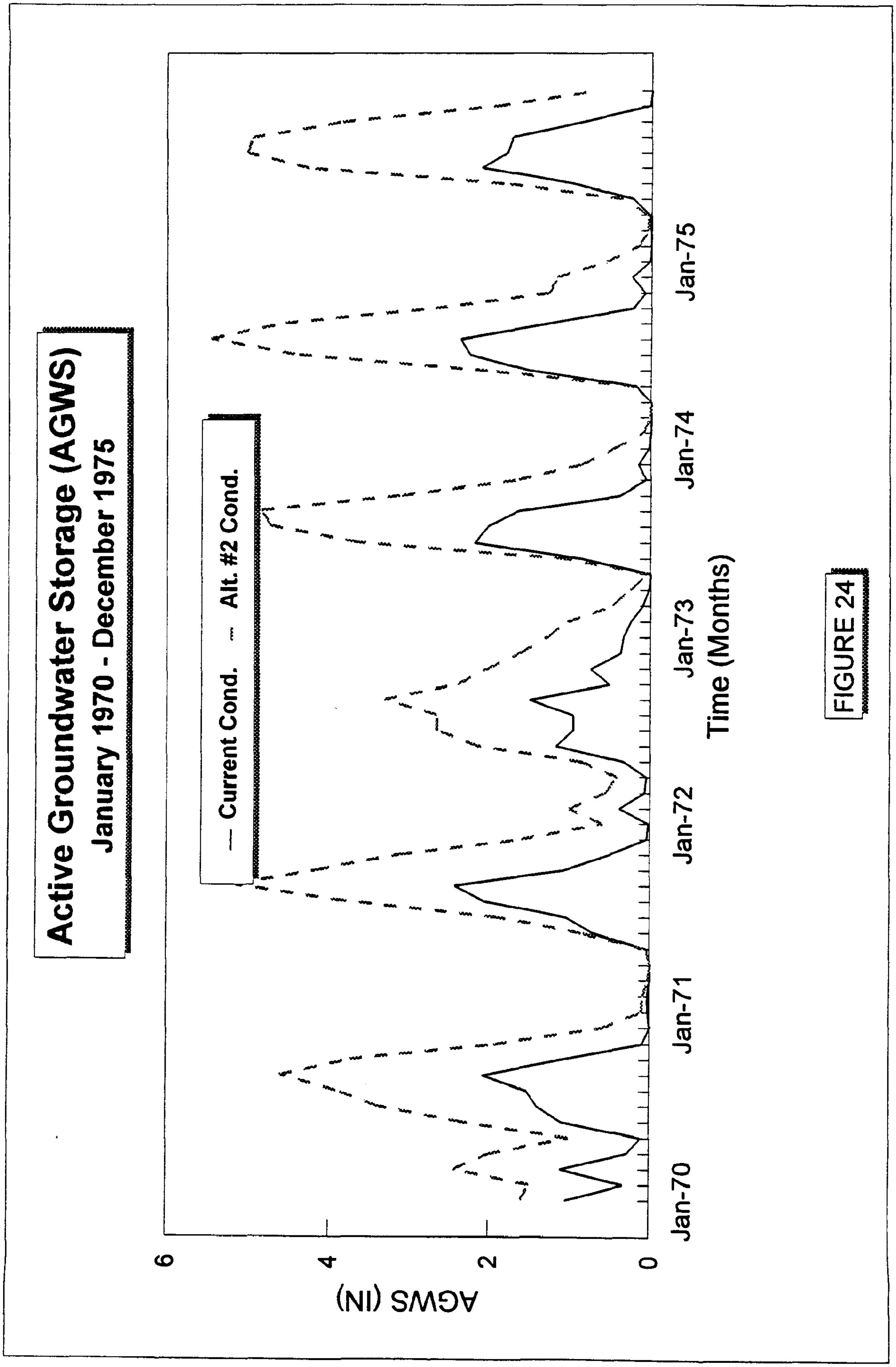
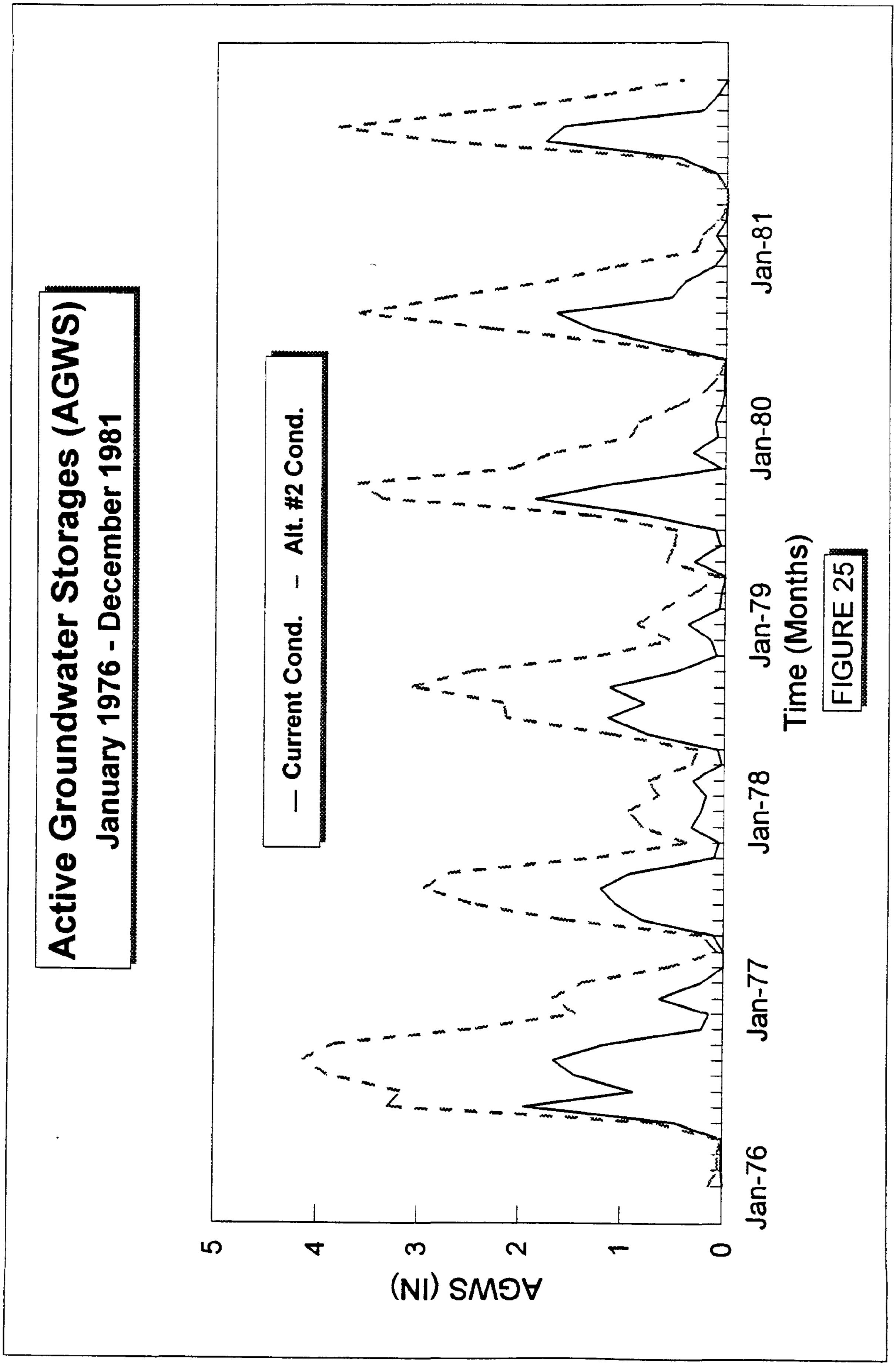


FIGURE 23


Active Groundwater Storage (AGWS)
January 1970 - December 1975
— Current Cond.
– Alt. #2 Cond.
AGWS (IN)
0
2
4
6
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)
FIGURE 24



Active Groundwater Storages (AGWS)
January 1976 - December 1981
— Current Cond. -- Alt. #2 Cond.
AGWS (IN)
0
1
2
3
4
5
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)

FIGURE 25

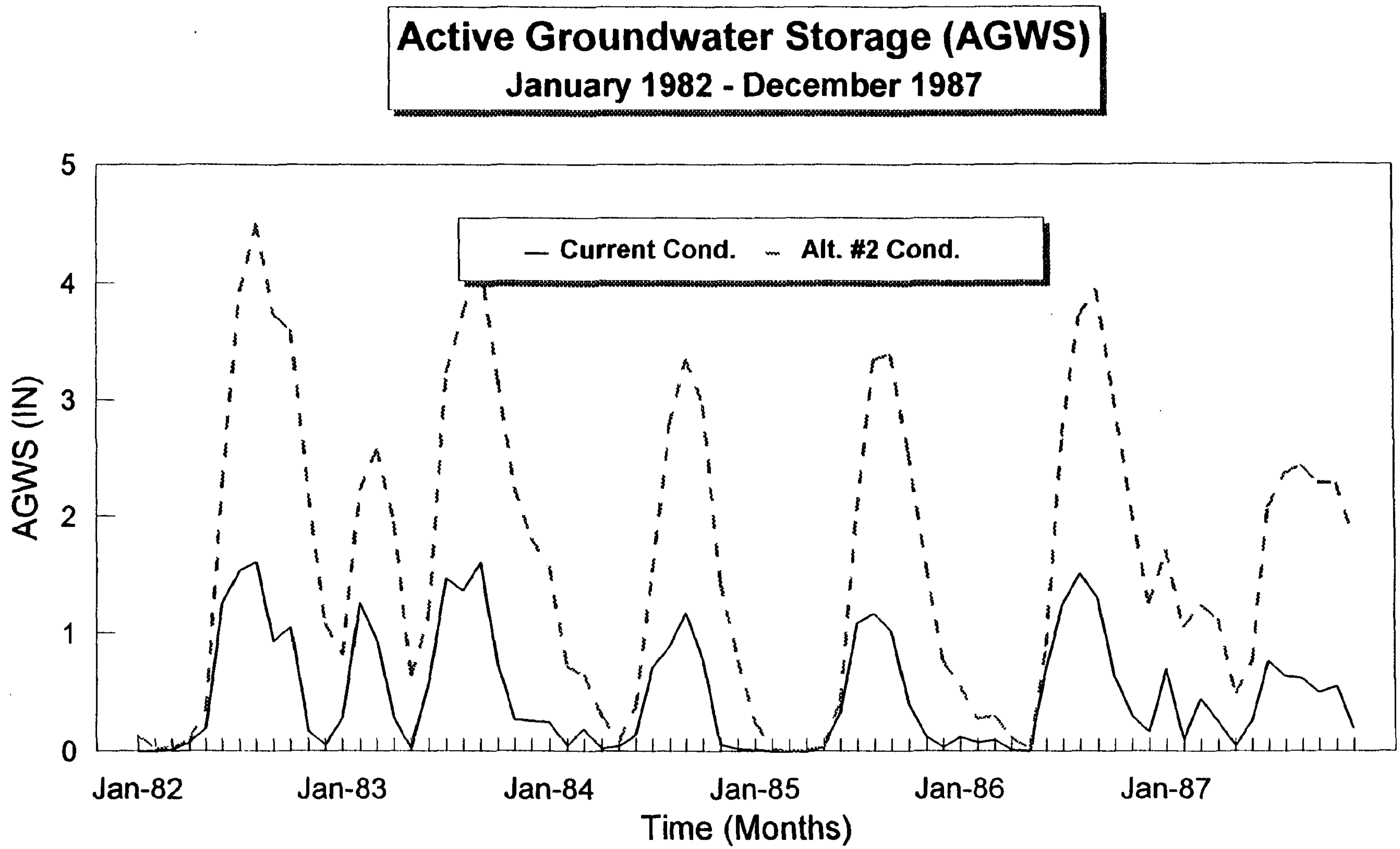
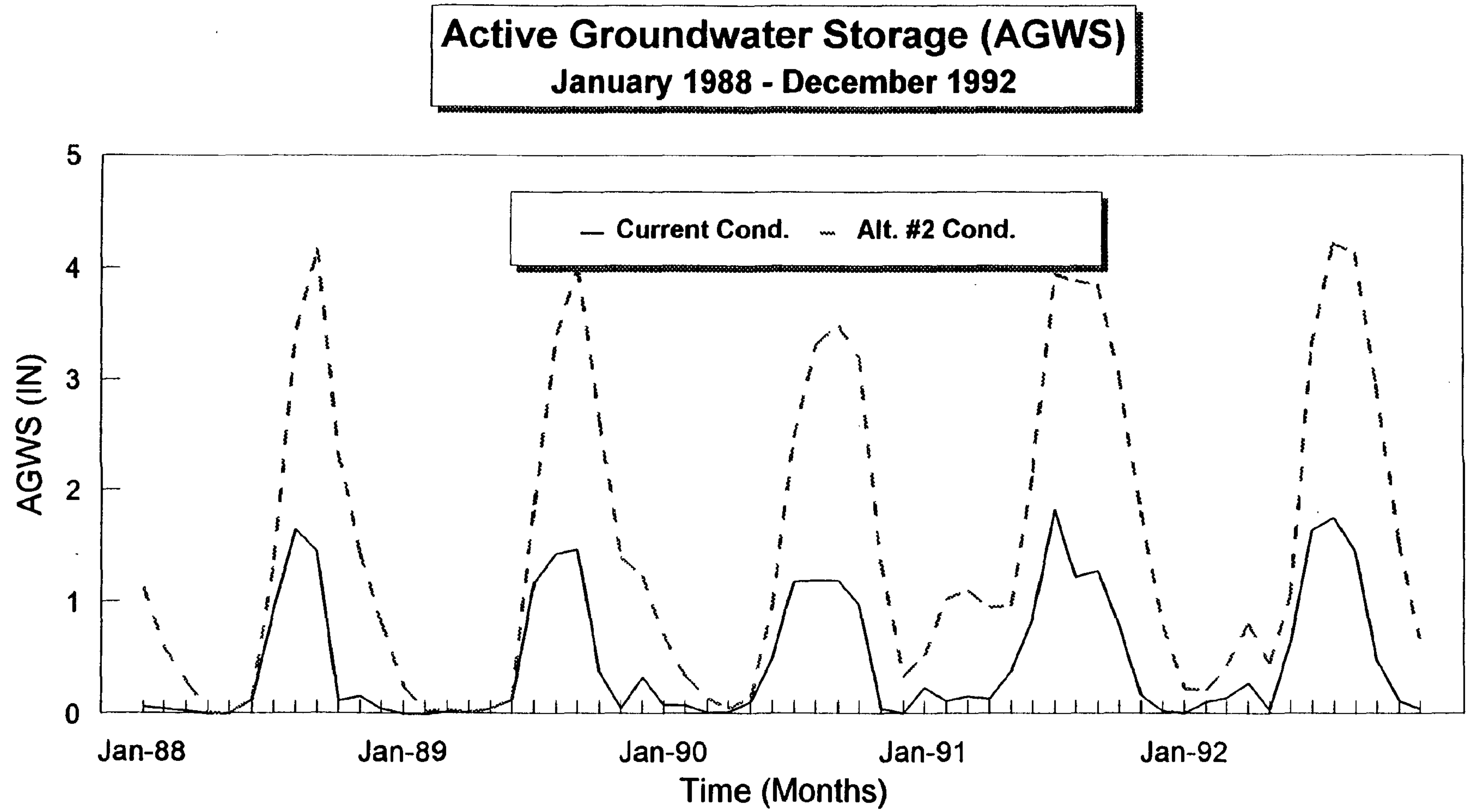

Active Groundwater Storage (AGWS)
January 1982 - December 1987
— Current Cond.
Alt. #2 Cond.
AGWS (IN)
0
1
2
3
4
5
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)

FIGURE 26



Active Groundwater Storage (AGWS)
January 1988 - December 1992
— Current Cond.
Alt. #2 Cond.
AGWS (IN)
0
1
2
3
4
5
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)

FIGURE 27

C. HYDROLOGIC PERFORMANCE OF ALTERNATIVE THREE

The overall water budget for alternative three relative to the existing conditions is also shown in Table 2. Similar to the results discussed for alternative two, without the canals to intercept the active groundwater outflow, runoff is significantly reduced.

Figures 28 through 39 show the average daily soil storages in the upper and lower soil zones and active groundwater storage for those land segments south of I-75 under alternative three scenario for the entire period of simulation. The relative increases in soil and groundwater storage values are similar to that of alternative two. The upper zone soil storage increased by six percent, lower zone soil storage increased by four percent and active groundwater storage increased by 62 percent. The active groundwater storage under alternative three was extended average annually for approximately one month longer than existing conditions.

D. ECONOMIC EVALUATION

A preliminary cost estimate analysis for structural implementation of the three alternatives are presented below. An economic benefit analysis under each alternative scenario has not been performed. The formulation of a recommended hydrologic restoration will, therefore, be based on the basis of least cost.

1) ALTERNATIVE ONE

The estimated cost for the installation of an interim diversion structure with three 48-inch gated RCP culverts with a spreader channel as illustrated in Table 3 is $171,354. This is an interim plan for partial restoration of the hydrology of SGGE. The Big Cypress Basin Board has presently proposed to implement the project in FY 1995.

Upper Zone Soil Storage (UZS)

January 1970 - December 1975

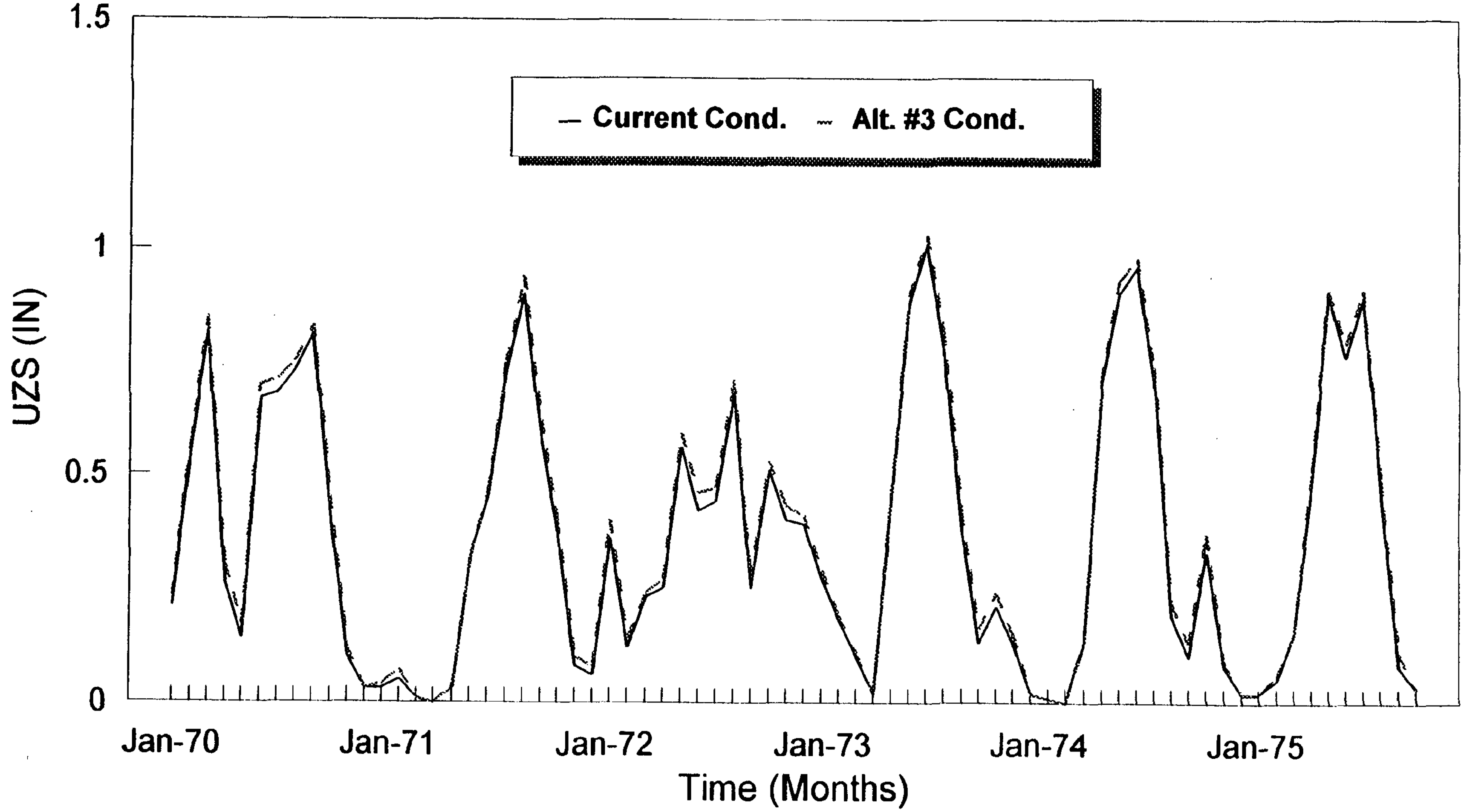
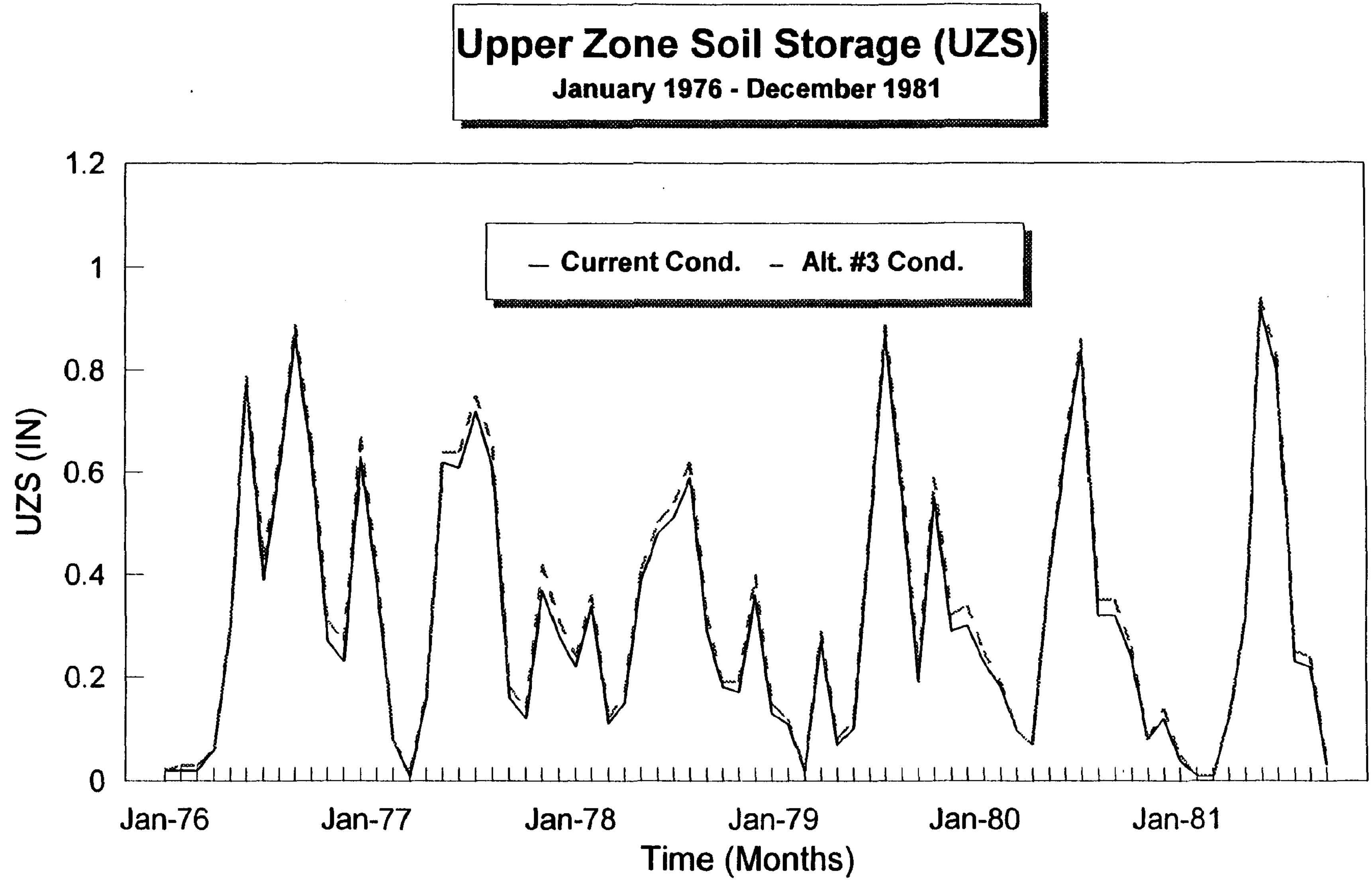


FIGURE 28



Upper Zone Soil Storage (UZS)
January 1976 - December 1981
— Current Cond. – Alt. #3 Cond.
UZS (IN)
1.2
1
0.8
0.6
0.4
0.2
0
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)

FIGURE 29

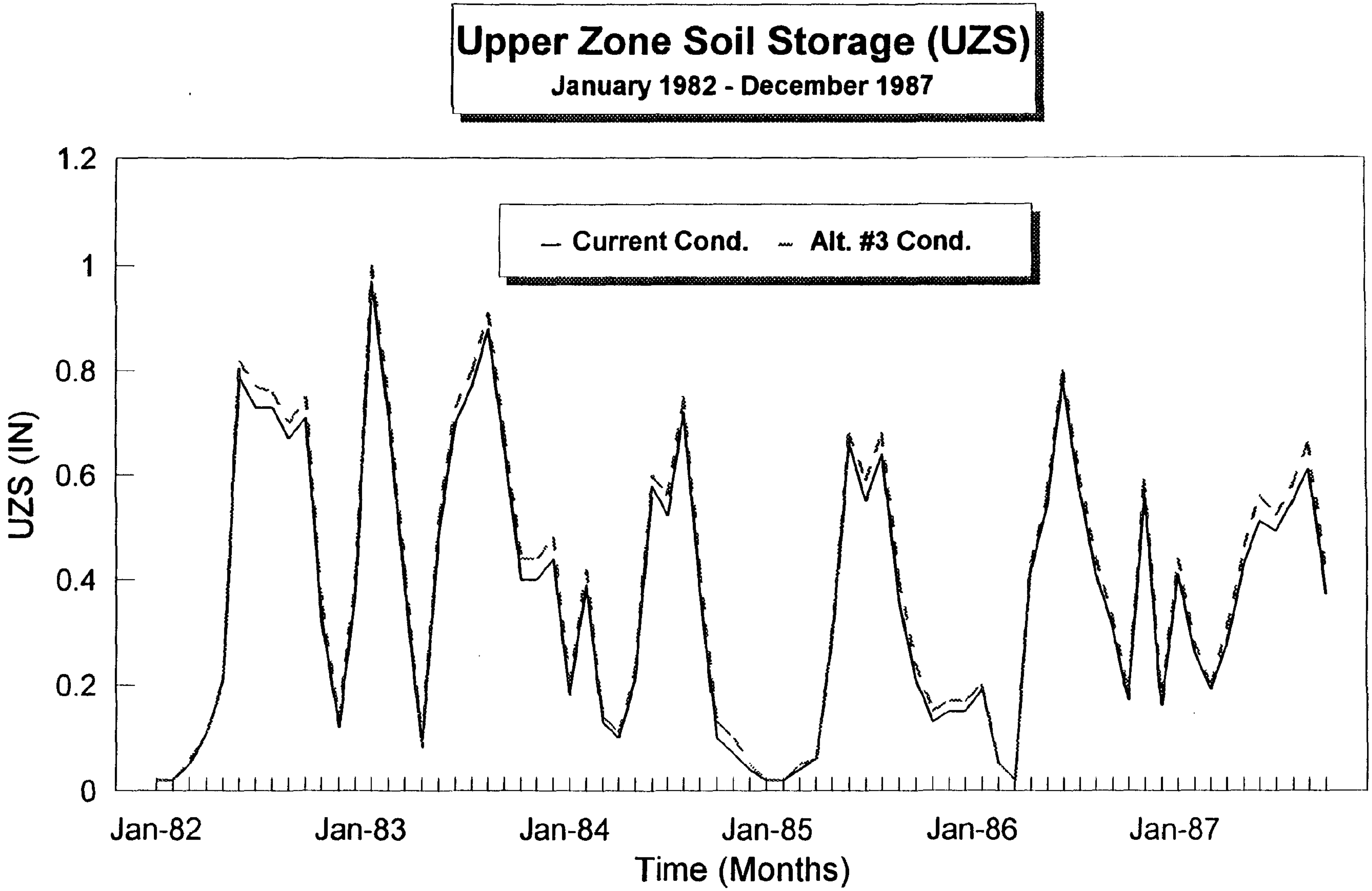

Upper Zone Soil Storage (UZS)
January 1982 - December 1987
Current Cond.
Alt. #3 Cond.
UZS (IN)
1.2
1
0.8
0.6
0.4
0.2
0
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)

FIGURE 30

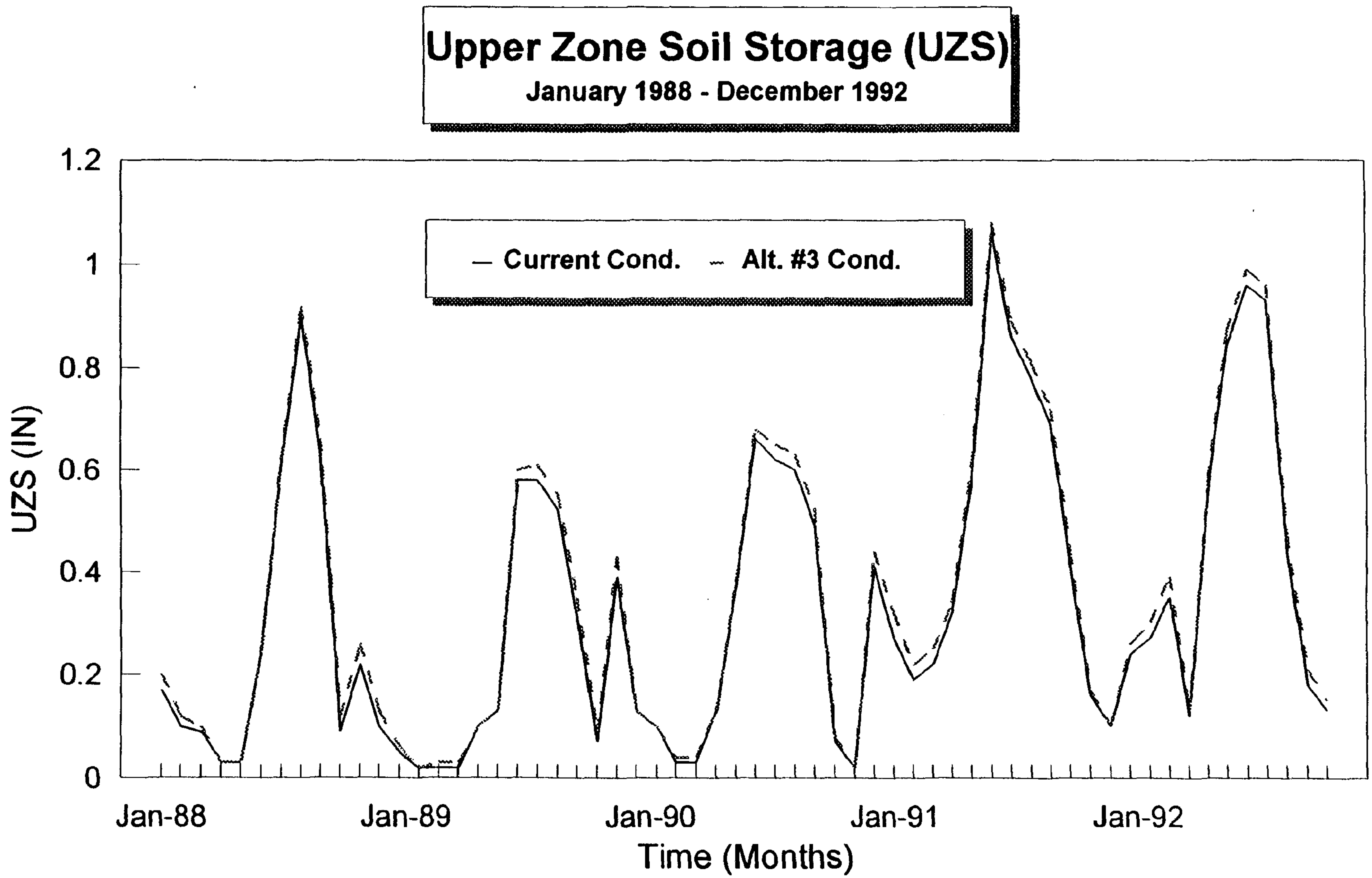

Upper Zone Soil Storage (UZS)
January 1988 - December 1992
— Current Cond.
-- Alt. #3 Cond.
UZS (IN)
1.2
1
0.8
0.6
0.4
0.2
0
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)

FIGURE 31

Lower Zone Soils Storage (LZS)

January 1970 - December 1975

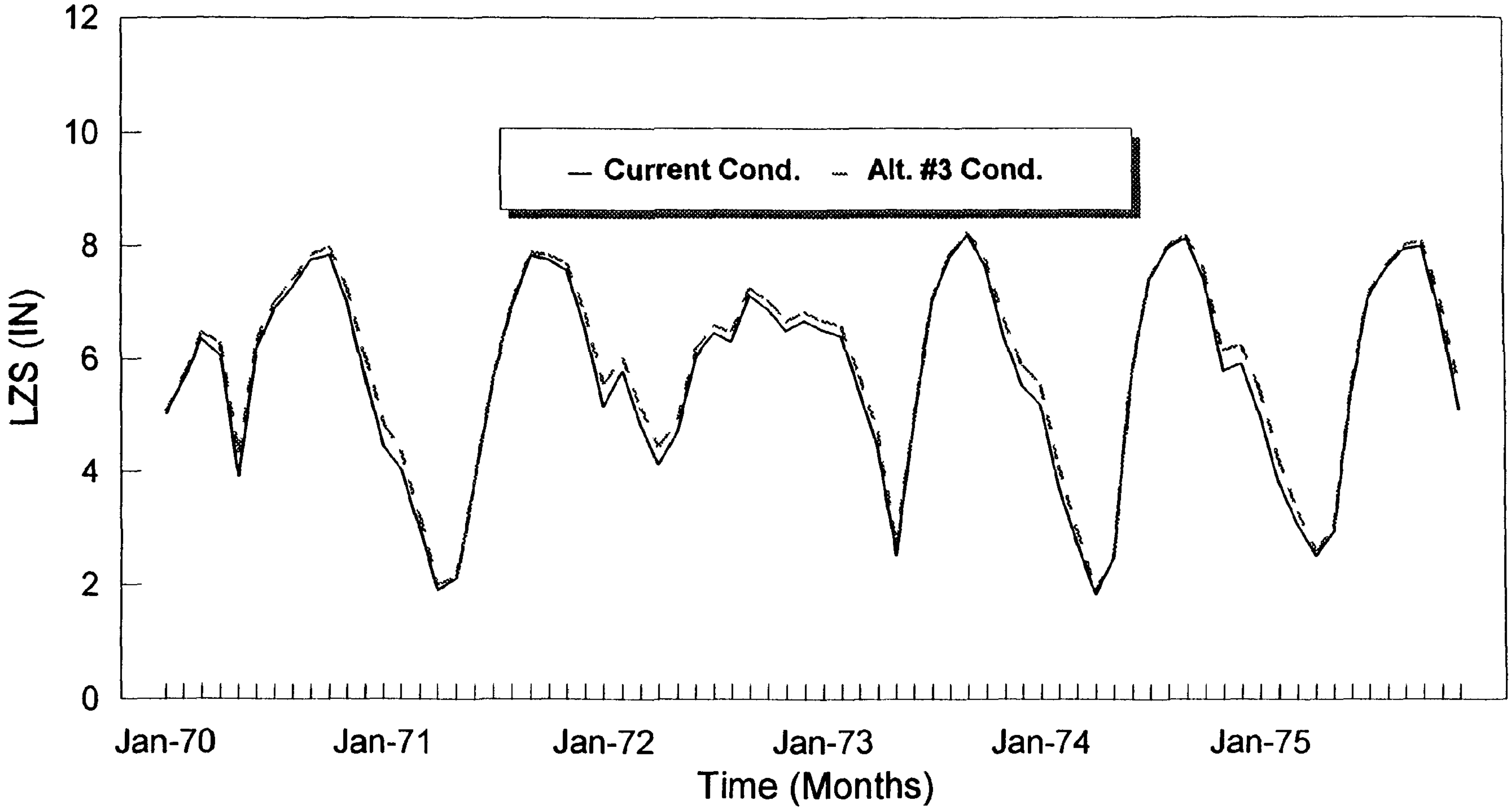


FIGURE 32

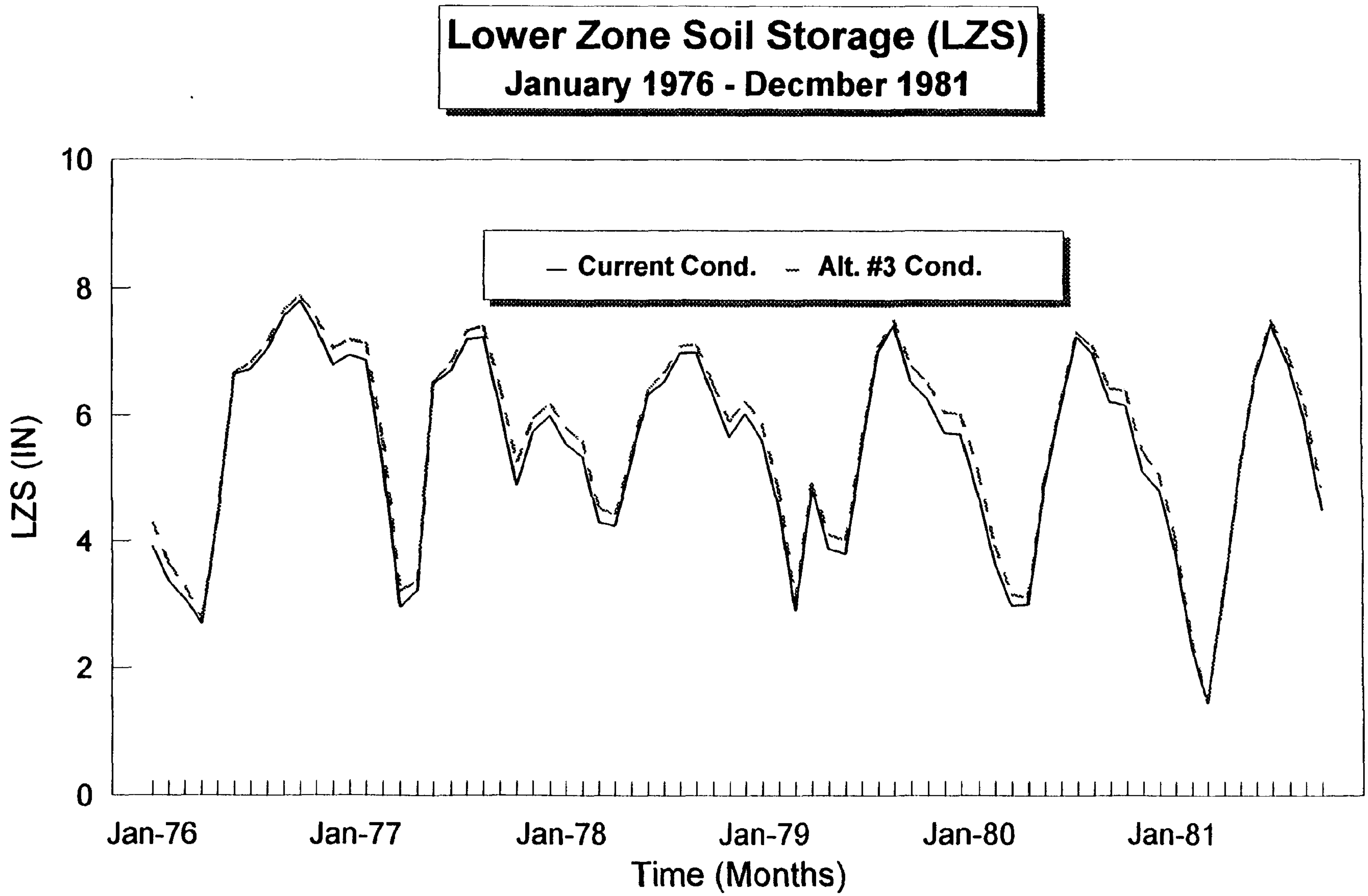
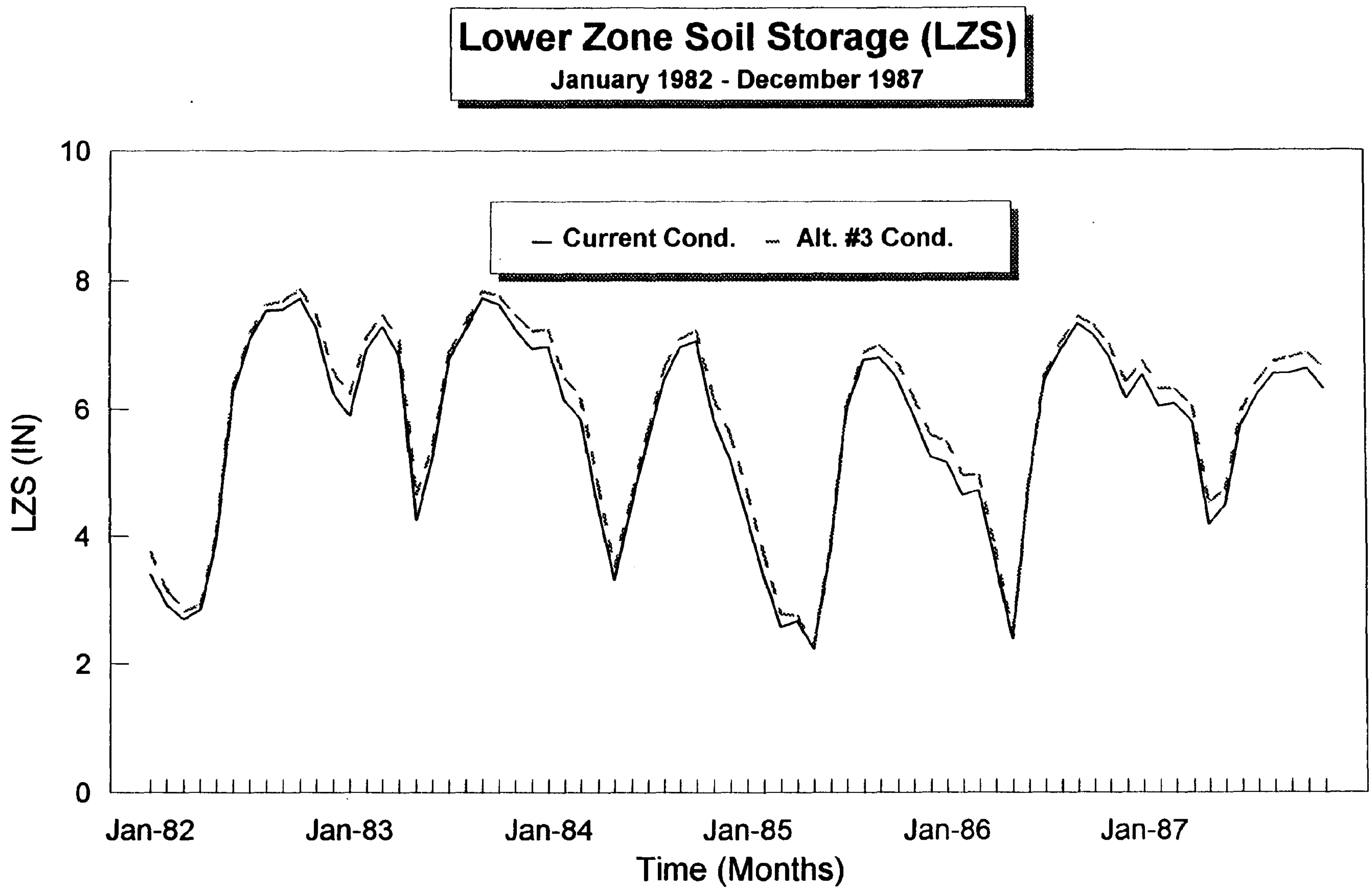

Lower Zone Soil Storage (LZS)
January 1976 - Decmber 1981
— Current Cond. -- Alt. #3 Cond.
LZS (IN)
0
2
4
6
8
10
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)

FIGURE 33



Lower Zone Soil Storage (LZS)
January 1982 - December 1987
Current Cond.
Alt. #3 Cond.
LZS (IN)
10
8
6
4
2
0
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)

FIGURE 34

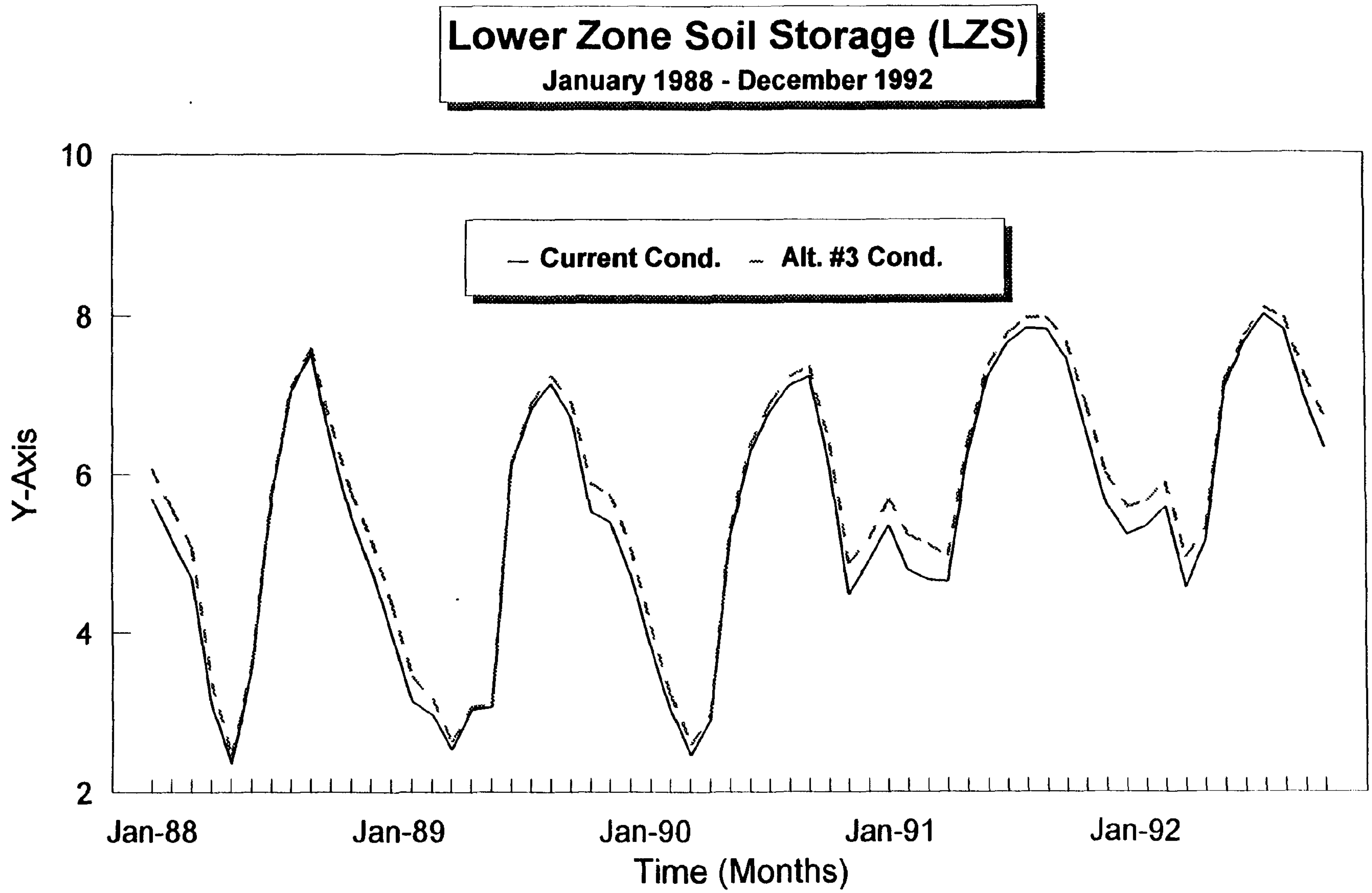
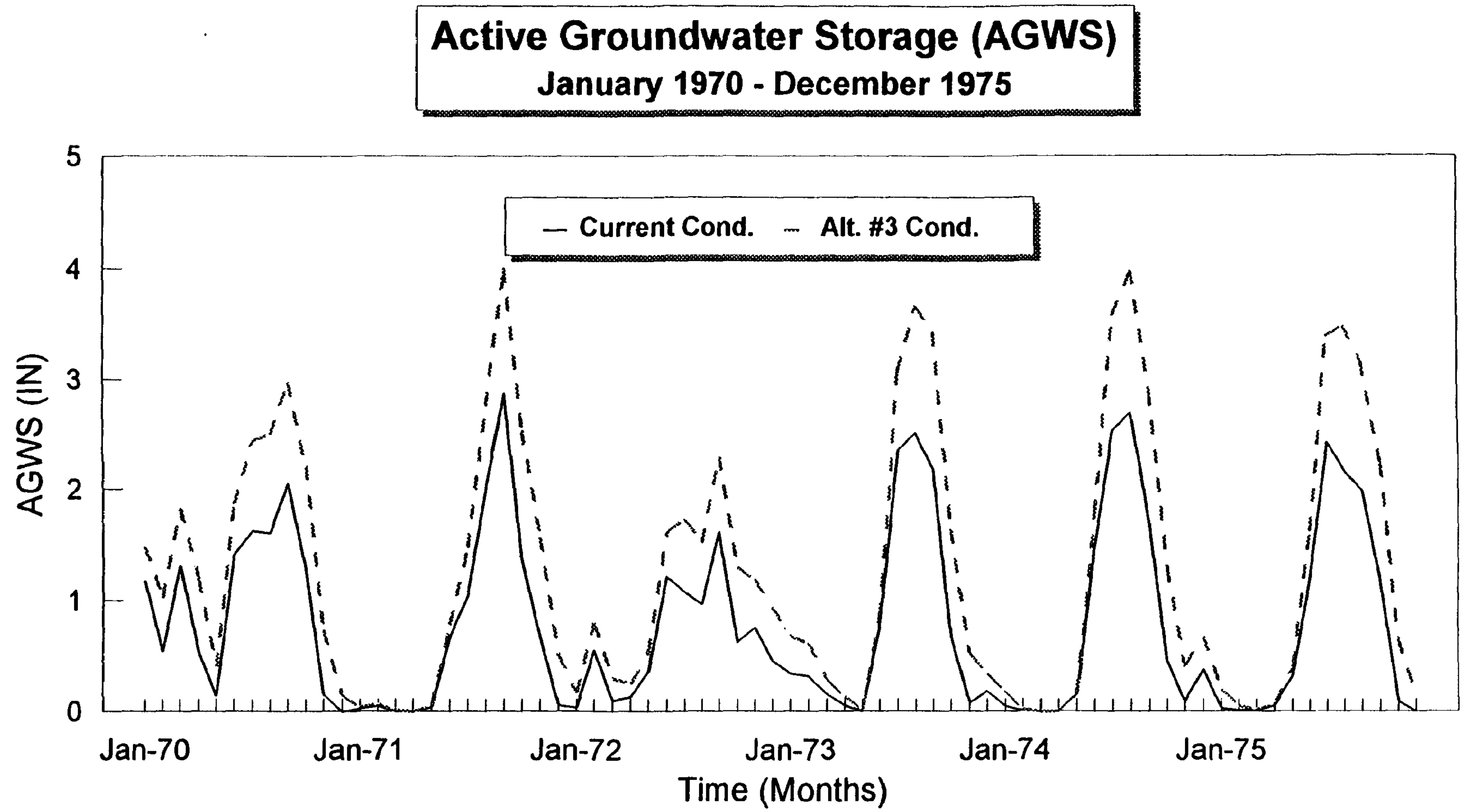

Lower Zone Soil Storage (LZS)
January 1988 - December 1992
— Current Cond.
-- Alt. #3 Cond.
Y-Axis
10
8
6
4
2
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)

FIGURE 35



Active Groundwater Storage (AGWS)
January 1970 - December 1975
Current Cond.
Alt. #3 Cond.
AGWS (IN)
0
1
2
3
4
5
Jan-70
Jan-71
Jan-72
Jan-73
Jan-74
Jan-75
Time (Months)

FIGURE 36

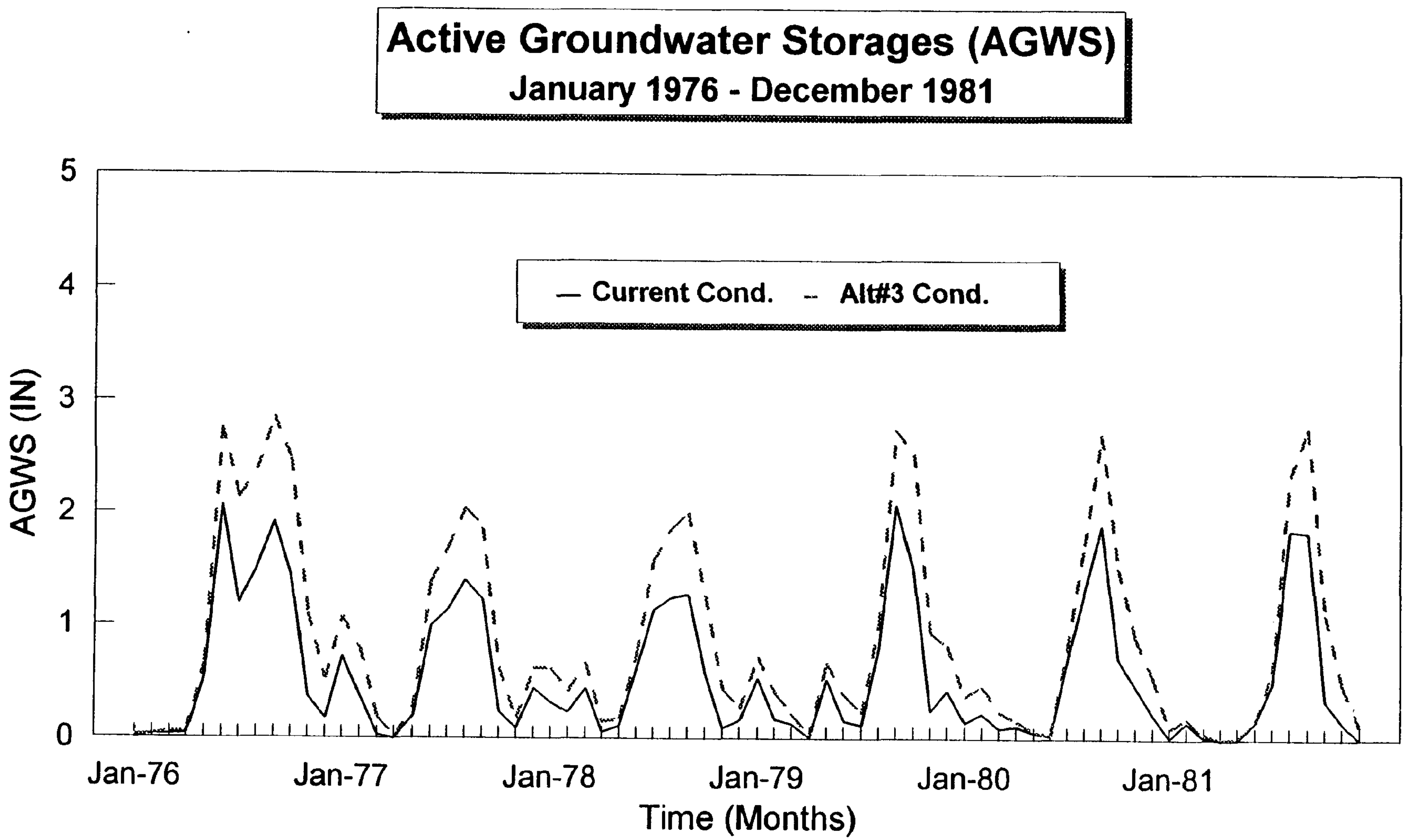
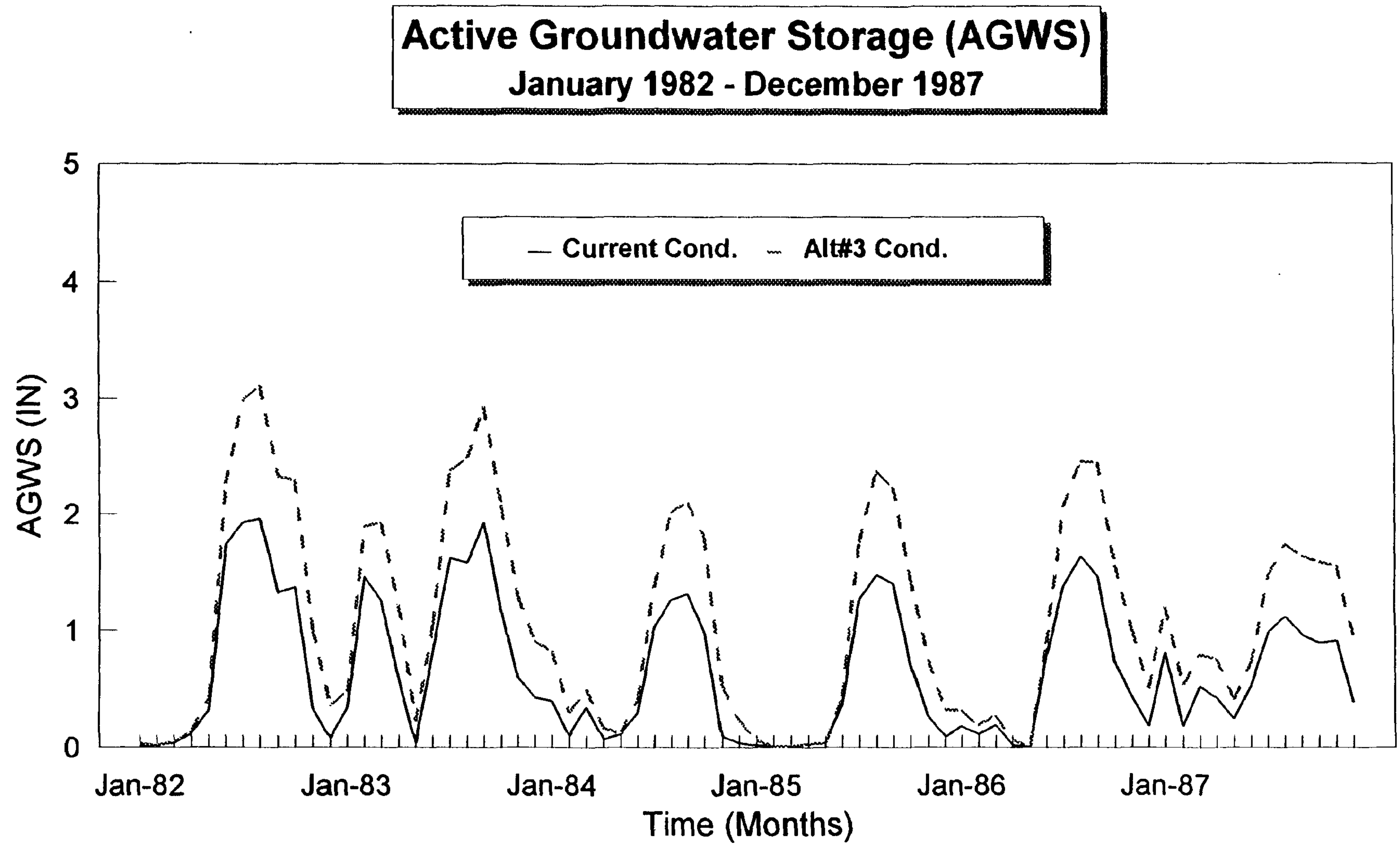

Active Groundwater Storages (AGWS)
January 1976 - December 1981
— Current Cond. -- Alt#3 Cond.
AGWS (IN)
0
1
2
3
4
5
Jan-76
Jan-77
Jan-78
Jan-79
Jan-80
Jan-81
Time (Months)

FIGURE 37



Active Groundwater Storage (AGWS)
January 1982 - December 1987
Current Cond.
Alt#3 Cond.
AGWS (IN)
0
1
2
3
4
5
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Time (Months)

FIGURE 38

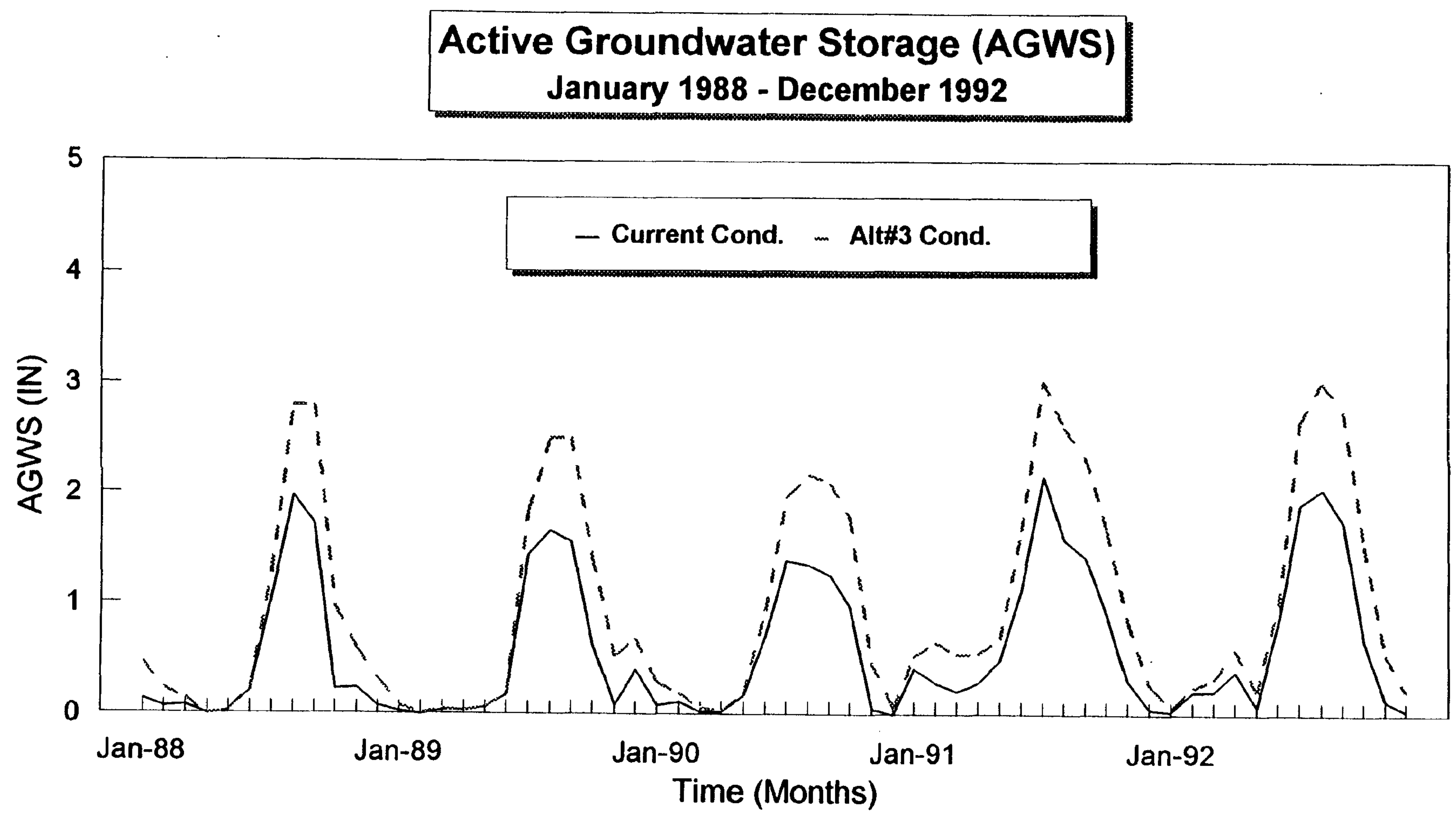

Active Groundwater Storage (AGWS)
January 1988 - December 1992
Current Cond.
Alt#3 Cond.
AGWS (IN)
0
1
2
3
4
5
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Time (Months)

FIGURE 39

TABLE 3

PRELIMINARY COST ESTIMATE FOR ALTERNATIVE ONE

DIVERSION STRUCTURE WITH THREE 48-INCH GATED CULVERT WITH SPREADER CHANNEL

	Item	Quantity	Unit Cost INC Labor, Equip & Material	Total Cost
A.	MOBILIZATION/DEMOBILIZATION	1	L.S.	$ 10,000
B.	STRUCTURE			
	1. Pipe Barrels	360 LF	115	41,400
	2. Flap Gates	3 each	2,630	7,890
	3. Sand Cement Endwalls	40	180	7,200
	4. Backfill			
	a. Pipe Bedding	87 yd^3	15	1,305
	b. Backfill	650 yd^3	6	3,900
C.	SITE WORK			
	1. Shell Base	83 yd^3	10	833
	2. Site Grading	1	L.S.	3,000
	3. Sodding	510 yd^3	3.50	1,785
D.	DEWATERING			
	1. Cofferdam			
	a. Design	1	L.S.	1,000
	b. Install & Remove	15 tons	1,100	16,500
	2. Equipment	1	3,500	3,500
	3. Excavation for Pipe	520 yd^3	3	1,560
	4. Excavation for Endwall	150 yd^3	3	450
	5. Clearing	1	L.S.	5,000
E.	SPREADER CHANNEL	16,818 yd^3	3	50,453
			Subtotal	$155,776
F.	CONTINGENCY @ 10%			15,578
			TOTAL	$171,354

2) ALTERNATIVE TWO

The preliminary cost estimate for implementation of a spreader channel and canal and road removal plan as identified under alternative two is illustrated in Table 4.

3) ALTERNATIVE THREE

The preliminary cost estimates for implementation of alternative three restoration measures which involve construction of two spreader channels, removal of selected road segments and installation of eleven canal plugs are illustrated in Table 5.

TABLE 4

PRELIMINARY COST ESTIMATE FOR ALTERNATIVE TWO

SPREADER CHANNEL WITH REMOVAL OF ROADS AND FILLING OF CANALS

A. FILLING THE CANALS

	Volume of Fill Required (cu. yd)	Cost per cu. yd	Total Cost
Miller Canal	1,694,308	$5	$ 8,471,540
Faka Union Canal	2,525,072	$5	$ 12,625,360
Merritt Canal	1,575,772	$5	$ 7,878,860
Prairie Canal	870,320	$5	$ 4,351,600
		Subtotal	$ 33,327,360

B. SPREADER CHANNEL

Excavation 255,493 cu.yd X $3/cu. yd =		$ 766,479
Clearing, Mobilization, Demolition, Diversion Channel During Construction, etc. @ 30%		$ 229,944
	Subtotal	$ 996,423

C. ROAD REMOVAL

$2500 per mile X 290 mi =		$ 725,000

D. PUMPS

Miller Canal		
25 HP Axial Flow Pump (Installed) @ $40,000/pump		$ 120,000
Faka Union Canal		
25 HP Axial Flow Pump (Installed) @ $40,000/pump		$ 360,000
Merritt		
25 HP Axial Flow Pump (Installed) @ $40,000/pump		$ 160,000
Pumping Cost		
Miller		
(24cfs) x (4 mo) = 1,862 MG/yr x $5/MG =		$ 9,308
Faka Union		
(117cfs) x (4mo) = 9,076 MG/yr x $5/MG =		$ 43,378
Merritt		
(33cfs) x (4 mo) = 2,560 MG/yr x $5/MG =		$ 12,800
	Subtotal	$ 705,486
	TOTAL	$ 35,754,269

TABLE 5

PRELIMINARY COST ESTIMATE FOR ALTERNATIVE THREE

SPREADER CHANNEL-ROAD REMOVAL-CANAL PLUG PLAN

A. CANAL PLUGS

	Volume of Fill Required (cu.yd)	Cost per cu.yd	Total Cost
Plug A1	742	$5	$ 3,710
Plug A2	987	$5	$ 4,935
Plug A3	1,231	$5	$ 6,155
Plug A4	1,231	$5	$ 6,155
Plug A5	1,831	$5	$ 9,155
Plug B1	2,076	$5	$ 10,380
Plug B2	1,316	$5	$ 6,580
Plug B3	2,231	$5	$ 11,155
Plug B4	1,658	$5	$ 8,290
Plug B5	2,231	$5	$ 11,155
Plug B6	3,564	$5	$ 17,820
		Subtotal	$ 95,490

B. SPREADER CHANNELS

Miller Spreader	
Excavation 12,457 cu. yd x $3/cu. yd =	$ 37,371
Clearing, Mobilization, Demolition, Diversion Channel During Construction, etc. @ 30%	$ 11,211
Faka Union Spreader	
Excavation 185,448 cu. yd x $3/cu. yd =	$556,345
Clearing, Mobilization, Demolition, Diversion Channel During Construction, etc. @ 30%	$166,903
Subtotal	$771,830

C. ROAD REMOVAL

$2500 per mile X 114 mi =	$285,000

D. PUMPS

Miller Canal	
25 HP Axial Flow Pump (Installed) @ $40,000/pump	$120,000
Faka Union Canal	
25 HP Axial Flow Pump (Installed) @ $40,000/pump	$360,000
Merritt	
25 HP Axial Flow Pump (Installed) @ $40,000/pump	$160,000
Pumping Cost	
Miller	
(24cfs) x (4 mo) = 1,862 MG/yr x $5/MG =	$ 9,308
Faka Union	
(117cfs) x (4mo) = 9,076 MG/yr x $5/MG =	$ 43,378
Merritt	
(33cfs) x (4 mo) = 2,560 MG/yr x $5/MG =	$ 12,800
Subtotal	$705,486
TOTAL	$1,857,806

4) SUMMARY OF ECONOMIC EVALUATION

The first cost of implementing the alternative restoration measures are:

Alternative One	$ 171,354
Alternative Two	$35,754,269
Alternative Three	$ 1,857,806

The economic evaluation of the selected alternatives was solely based on the preliminary estimates of the initial construction costs. Alternative one is an interim plan for partial hydrologic restoration of SGGE, primarily to reduce the voluminous point discharges of freshwater to the Faka Union Bay Estuary. The project does not involve acquisition of private lands except a small parcel of land for construction easement.

Alternative two was hydrologically evaluated to investigate the effect of a large scale restoration measure relative to the historic conditions rather than as an economically feasible alternative. It is apparent that the cost of implementing such a plan will be astronomical. A quantitative economic benefit analysis of each alternative was not performed at this time. The formulation of a recommended plan will therefore be based only on cost of implementation.

E. HYDROLOGIC IMPACT ASSESSMENT

Alternative one is only a partial restoration plan to take advantage of presently available public lands. It would rehydrate a small portion of SGGE. The sheetflow created will enhance the functioning of the adjacent wetlands during the dry season. Storm flows will continue to be discharged at the Faka Union outlet during the wet season. However, a reduction of up to 250 cfs of freshwater discharge point loads to the Faka Union Bay will be achieved which will contribute towards enhancing the ecological health of the estuary. This alternative does not inundate privately owned land. There will be no impact on upstream flood stages.

For alternative two, there would be no adverse impact on the flood protection for the area north of I-75 because the pumps will force the water south. The areas south of I-75 would be seasonally flooded. The lower zone soil moisture storage levels show an average annual increase of one to two months in duration as the dry season approaches. This plan would preclude residential development south of I-75, and necessitate complete public ownership of the lands in SGGE.

The hydrologic impacts of alternative three are similar to alternative two. The pumping stations would be required to maintain flood protection north of the alley. Large areas south of I-75 would be seasonally flooded and therefore, would necessitate public ownership of those lands. For both alternative two and three, a low berm along the perimeter of the Port of the Islands complex will be necessary to prevent flooding from restored surface flows.

VIII. RECOMMENDED PLAN

On the basis of the above hydrologic-hydraulic, and economic evaluations, and assessment of impacts of three alternative measures, the alternative three plan involving construction of two spreader channels, eleven canal blocks and removal of selected segments of roads is recommended for implementation of the restoration of SGGE. Alternative one is a partial restoration plan, and only accomplishes limited objectives of the project. Alternative two is not economically feasible. Alternative three would reestablish sheetflow and eliminate the point flow discharges through the Faka Union Canal and achieve the various objectives of the project.

IX. CONCLUSIONS

The previous studies by the Army COE and others on the feasibility of modifying the Faka Union Canal drainage basin for restoring the hydrology and ecology of the area were based on hydrologic-hydraulic analysis with event-based models. This study used a state of the art methodology to simulate the continuous process hydrology of SGGE for a 23-year period and to predict the behavior of the water table and its effect on soil storage and surface water flow under three alternative scenarios. Although certain modifications to the model are needed to more closely simulate South Florida hydrology, the model provided a fair representation of the existing hydrologic conditions of SGGE.

The number of alternative restoration measures analyzed were limited due to the limited time frame available within the scope of the grant contract. More alternative measures will be considered and evaluated with the calibrated model to develop an economically and environmentally viable plan to restore the hydrology and ecology of this unique region of south Florida.

APPENDIX A

PERLND	pervious land module
PETMAX	air temperature which signals a change in ET calculation only used if snow is considered
PETMIN	air temperature which signals a change in ET calculation only used if snow is considered
PLS	pervious land segment
PREC	precipitation
PWATER	Pervious Land-Water Budget Simulation
RCHRES	Reach-Reservoir
RFAVGM	Program that averages daily rainfall at selected stations
RO	Runoff
ROVOL	runoff volume
SUPY	Water Supply
SURS	surface storage at the start of the simulation (in)
TAET	total simulated evapotranspiration
UZS	upper zone soil storage at the start of the simulation
UZSN	upper zone nominal soil storage (in)
WMD	Watershed Data Management, program ANNIE file

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